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SPECIAL FEATURES

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4600 Prospect Avenue

AGATHON ALLOY STEELS

THE average motor car owner little understands or appreciates the tremendous stresses and strains to which the vital parts of his car are subjected while speeding over country roads—up hill and down vale. He has little conception of the grating, grinding, wearing effect of steel upon steel that takes place in axle housing, transmission case and under the hood of his car.

But the car builder knows. And in seventy to eighty of the highly stressed parts of his car he uses nothing but super-steels—alloy steels of such analysis as will best resist wear, shock and strains.

In most of America's best known cars these vital parts are made of one of the many analyses of Agathon Alloy Steels. Each is produced to meet precise requirements. Charts showing analysis and physical properties of nineteen popular alloy steels are given in our booklet, "Agathon Alloy Steels," which will be sent on request.

We have daily production in all kinds of commercial alloy steels such as—

Nickel
Chrome-Nickel
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Molybdenum
Chrome-Molybdenum
Nickel-Molybdenum
Vanadium
Chrome-Vanadium
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Blooms Billets
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TRANSACTIONS

of the

American Society for Steel Treating

Vol. IV Cleveland, December, 1923 No. 6

OPPORTUNITY

ARE you ready when *Opportunity* knocks at your door? Will you know when *Opportunity* really knocks? Preparation for that time must be a continual process of observation, study and application of one's mental capacities along those lines in which he is best adapted. *Opportunity* is ever-ready and is almost constantly knocking, but in most instances we are not ready, and cannot acknowledge the call. Preparedness should be our watchword at all times, as it is only through being prepared, that we are able to accept outstanding opportunity as it is presented.

There are, of course, many types and varieties of opportunity. Most of us take advantage only of mediocre conditions of life. It is only through expending great effort in both mental and physical endeavor, that we can expect to arrive at an enviable position or station in life. Usually one gets out of life about what he puts into it, and likewise one's services are in demand in just about that proportion that he has made himself more valuable than his colleagues or co-workers. Initiative must be an outstanding factor. Those individuals who display a high order of initiative are selected and presented with that intangible something we call opportunity.

The study of personal success involves many attributes of a person. Success is attainable by all, but it cannot be attained without courage and work. The little things—the details, are of paramount importance. Do you ever ask yourself whether or not you do the little, minor details, well? If not, it would be well for you to inquire into this matter. Should you determine that, perhaps, you have been somewhat negligent, it would be well for you

to turn to a new leaf in your book of life, and resolve to give the details of your daily work, the attention that they really deserve. It is common knowledge that if the bricks in a wall are poorly made and poorly laid, there can be no other result but a weak structure.

The man who does a task only moderately well will be only moderately compensated. The man who does the task very much better than anyone else, will be compensated in proportion. The world is constantly looking for those who can do things better than anyone else can do them, and it is to those who are prepared to accept the opportunity as it comes, who will have the straight road to success.

Be prepared, and the opportunity for you to show your capacity will be ever-present.

THE BUSINESS SITUATION

WHEN the records of the year 1923 are entered in the annals of American business, the year will be described as one of prosperity just as surely, although not so emphatically, as 1921 will be remembered as one of depression.

In spite of the muddled conditions which have been prevalent in Europe for the past five years, and which still seem to be a long way from being settled, America has shown a healthy business growth especially in the past two years.

During the summer, declines appeared in a number of lines, but this condition has changed to one of gains, especially in the automobile production, building construction, copper, and other nonferrous metals. Stability and steadiness prevail.

Conditions in the iron and steel industry are not so encouraging, with prices falling, orders declining, and output tending downward. The mills are producing at about 80 per cent of capacity and the industry is permeated by a spirit of caution. However, with increases in railroad orders and the recent favorable earnings report of the United States Steel Corp., lend a favorable tone to the situation.

All in all, the general business forecast is that basic conditions are sound, and that for the next six months business prosperity will prevail.

WINTER SECTIONAL MEETING

THE winter sectional meeting will be held under the auspices of the Rochester Chapter of the Society on Thursday, Jan. 31, and Friday, Feb. 1, 1924 with headquarters at the Hotel Seneca, Rochester, N. Y.

The program for this meeting is as follows:

Thursday, January 31

11:00 a. m. Registration and Technical Paper, at Seneca hotel.

12:30 p. m. Luncheon, at Seneca hotel.

2:00 p. m.-5:00 p. m. Three Technical Papers.

6:30 p. m. Joint Banquet of Rochester Chapter of the American Society for Steel Treating and the Chamber of Commerce at the Chamber of Commerce building.

Toastmaster—Doctor Rush Rhees, president of the University of Rochester.

Speaker—Doctor G. K. Burgess, president of the American Society for Steel Treating, and director of the Bureau of Standards.
"Relation of the Government to Industry."

Friday, February 1

6:30 p. m. Joint Banquet of Rochester Chapter of the American Society for Steel Treating.

Plant visitation: I. L. Nixon, chairman of the committee, has arranged for visiting the following plants in the order named: Gleason Works, the Taylor Instrument companies; the Bausch-Lomb Optical company; the research laboratory of Eastman Kodak company.

A complimentary luncheon will be served to visiting members and guests in the private dining room at the Bausch and Lomb Optical company.

The morning and afternoon technical sessions, as well as the luncheon will be held at the Hotel Seneca, the headquarters for the meeting.

This meeting will be one of the best sectional meetings the society has held and the papers for the occasion are going to be

HOTEL SENECA
Winter Sectional Meeting Headquarters

well worth while. The complete list of speakers will be announced in the January issue of TRANSACTIONS.

Here is an opportunity for the members to again get together for the exchange of ideas and renewal of acquaintance, and every member should make every possible effort to be present.

Please make your hotel reservations early and directly with the hotel management, the rates for which are as follows:

Rooms equipped with	Single	Double
Hot and cold running water	$2.50	$ 3.50
Shower baths	2.50	4.00
Shower baths	3.00	4.50
Shower baths	3.50	5.00
Tub baths	3.00	5.00
Tub baths	3.50	5.00
Tub baths	4.00	6.00
Twin beds and shower baths		5.00
Twin beds and tub baths		7.00
Two double beds and tub bath (4 persons)		10.00

Parlors $3.50 and up, per day.

In making reservations, it is important that the hour of arrival be given, as reservations are not held after 10 p.m., except on special request.

Kindly make second choice, in the event your first choice of rate is not available.

INFORMATION OF INTEREST TO MEMBERS OF THE SOCIETY

THE board of directors of the American Society for Steel Treating at its regular meeting in Washington, unanimously voted to have a digest of the minutes of their meetings published

in future issues of the TRANSACTIONS. It is hoped the members at large will take greater interest in the work of their national officers and it is believed that this action will meet the hearty approval of the entire membership.

Your attention is, therefore, directed to the digest of the minutes of the November meeting published on the succeeding pages of this issue of TRANSACTIONS.

VOLUME IV OF TRANSACTIONS COMPLETED

THIS issue of TRANSACTIONS completes Volume IV. As previously announced, TRANSACTIONS will be issued in two volumes per year. Volume IV covers the period from July, 1923, through December, 1923. Volume V will include the period from January, 1924, through June, 1924. The index for Volume IV is now ready and copies may be obtained upon request. Address American Society for Steel Treating, 4600 Prospect avenue, Cleveland, O.

EDUCATIONAL ACTIVITIES OF THE CHAPTERS

THE special educational activities of a number of our chapters is indeed a most worthy and commendable endeavor. Among those chapters which are either fostering courses in metallurgy or metallography under their own supervision or in co-operation with local educational institutions are, Lehigh Valley, Philadelphia, Chicago, Tri City, Milwaukee and Cleveland. The Lehigh Valley and Pittsburgh chapters have offered prizes for the best paper written upon the subject of steel and its treatment, to be written during the current year by engineering students at Lehigh university, Carnegie Tech and the University of Pittsburgh. The Philadelphia chapter has awarded three scholarships to shop men for the evening course in metallurgy given at Temple university. The other chapters working in co-operation with local educational institutions are conducting evening courses for the benefit of their members. A very active interest has been shown in this work in all of these chapters, and it shows how the society may assist in the work of educating its co-workers.

REPORT OF THE MEETING
of the
BOARD OF DIRECTORS OF THE AMERICAN SOCIETY FOR STEEL TREATING

Meeting Held at the
Bureau of Standards, Washington, D. C., Friday, November 2, 1923, at 10:00 a. m.
All Officers and Directors Present

AN UNAUDITED financial report of the fifth annual convention of the society, held in Pittsburgh, October 8-12, 1923, was presented. The report showed total receipts from all sources to be $38,848.48, while the expenditures amounted to $26,879.30, leaving an excess of income over expenditures of $11,969.18. It was pointed out, however, that this report did not carry the overhead for the remainder of the year until January 1, and that there were a few outstanding bills not yet received. Upon motion duly made and carried, the unaudited report was accepted and ordered filed.

Consideration was then given to the selection of a convention city for the sixth annual convention to be held in 1924. Invitations were received from New York, Boston, Atlantic City, Buffalo, Cleveland, Chicago, and Los Angeles. Inasmuch as four of the previous five conventions of the A. S. S. T. had been held in central or western territory, the board, by unanimous vote, decided that the 1924 convention should be held in Boston, unless the convention committee, to be appointed, should report otherwise; and that the dates for holding the convention should be decided by the convention committee after their investigation. The President then appointed the following convention committee: Chairman, Doctor Burgess; members, Messrs. W. S. Bidle, F. P. Gilligan, and W. H. Eisenman.

F. P. Gilligan was appointed by the Board as their representative on the local convention committees of the convention city.

The location for the sectional meetings for 1924 was then considered. Owing to the proposed location of the annual

convention in Boston, a rearrangement of cities for holding sectional meetings, as previously determined upon, was thought advisable. It was unanimously determined that the winter sectional meeting should be held in Rochester, N. Y., in January, and the spring sectional meeting be held in Tri Cities, the exact dates to be determined later.

The next item for consideration was the awarding of the Henry Marion Howe medal. The Final Awards committee submitted a report in which they recommended that no Howe medal be awarded for the year ending July 31, 1923. After some discussion, upon a majority vote, the report of the committee was accepted and the committee discharged.

President Burgess and past-president Lynch presented a report of their attendance at the Henry Marion Howe memorial service held in New York.

Consideration was next given to the appointing of committees as presented by President Burgess. The committees appointed by the President received the unanimous approval of the Board.

FINANCE COMMITTEE: Chairman, Dr. Zay Jeffries; members, Roy McKenna, J. M. Watson, J. V. Emmons and George L. Norris.

PUBLICATION COMMITTEE: This committee was approved, as at present constituted with the addition of two new members (J. L. McCloud and A. W. F. Green); the committee is as follows: Chairman, Prof. H. M. Boylston; Ray T. Bayless, vice chairman and secretary; members, Messrs. C. M. Johnson, A. H. d'Arcambal, S. C. Spalding, W. H. Laury, H. Freeman, E. E. Thum, E. W. Ehn, R. S. Archer, J. L. McCloud and A. W. F. Green.

MEETINGS AND PAPERS COMMITTEE: Chairman, L. D. Hawkridge; members, Messrs. H. C. Goodwill, C. E. McQuigg, Benjamin Shepherd, O. T. Muehlemeyer, and Ray T. Bayless, secretary.

CONSTITUTION AND BY-LAWS COMMITTEE: Chairman, S. M. Havens; members, Messrs. W. P. Woodside, H. J. Stagg Jr., Jerome Strauss, and H. Kenneth Briggs.

MEMBERSHIP COMMITTEE: Chairman, W. E. Blythe;

members, Messrs. Arthur Henry, Robert Schenck, and Sam Shagaloff.

It was moved and unanimously carried that there should be no Library committee appointed for the present year. However, the national secretary was instructed to send a letter of appreciation to Dr. J. Culver Hartzell, for his services as chairman of the committee in the past.

The next question taken up was that of the appointment of a Research committee as well as the field it was to cover. After some discussion it was moved and carried that a committee consisting of H. J. French, chairman, with Messrs. Brophy and Merica should be appointed to have a meeting and report back to the Board whether or not there was a field for a Research committee, and if so, what that field might be.

NOMINATING COMMITTEE: President Burgess, in co-operation with the Board then selected the following five chapters from which one member of the Nominating committee should be appointed by the chapter: Boston, Detroit, Schenectady, Cincinnati, and Tri City. It was understood, however, that this committee was not to be announced until January 1, 1924, so as to determine if possible, whether or not the new scheme for the nomination of national officers, as embodied in the new constitution, might be made effective by having the new constitution and by-laws adopted in time for the newly constituted Nominating committee to have a meeting at the next annual convention.

The question of a Standards committee was next presented for consideration, and the recommendation made at the annual meeting that the name be changed from "Standards" to "Recommended Practice" committee, received the approval of the Board. R. M. Bird then gave the following scheme of organization of a Recommended Practice committee:

"The recommended Practice committee should consist of 7 to 9 members, whose work it would be to plan and actively expedite the work of the committee. This committee should meet about twice a year, and there should be a paid secretary to carry on the business of the committee. Such a committee would function in the following manner: As an

example, should an individual suggest that it would be well to established a recommended practice for the heat treatment of locomotive parts, the first information that the Recommended Practice committee should have is whether or not there is a real need for such a recommended practice. It would then be the duty of the secretary of the committee to develop whether or not there is that need. This work could be done either through visits, letter, personal contact, or by proper committees in the chapters. The results of this circularization would then come back to the Recommended Practice committee. If it is found that there is a real need for recommended practice on the subject under consideration, the committee would then appoint a sub-committtee and assign it this work. This sub-committee, in co-operation with the secretary, would collect and compile proper recommended practice on that subject. When the sub-committee's work is completed the report should be presented to the Recommended Practice committee and could be handled as follows:

1. The report tentatively accepted and the sub-committee discharged.

2. The report might be referred back to the sub-committee for further consideration.

3. The report could be dropped.

If the report was tentatively accepted and the sub-committee discharged, the report should then be referred to the membership of the society through the chapters, or by a special committee in the chapter appointed to consider such matters. If, then, the report comes back from the membership with no serious objections or corrections, it then comes out as a tentative recommended practice of the society for a period of one year. At the end of the specified time, the tentative recommended practice should come back to the membership of the society, either by letter ballot or before the annual meeting, and if the report is approved, it would become a recommended practice." Mr. Bird further added that the supervision of the data sheets, as well as indicating the subjects on which data sheets should be written, and acting as a clearing house for their final approval, could well be a portion of the work of the Recommended Practice committee. It was

felt that such a committee when properly organized would have an evolutionary effect in producing valuable recommended practices, and would develop quite rapidly after the work was started. It was thought, further, that as the membership at large realized the scope of the committee and the work it is capable of doing, they themselves will initiate subjects, and even prepare recommended practices for the consideration of the committee.

The Board was very favorably inclined toward the matter of an organization as proposed by Mr. Bird, and it was unanimously agreed to organize a committee on recommended practice along the lines indicated.

W. S. Bidle, chairman of a committee appointed at the meeting of the Board on October 9th, reported that the committee considered it advisable to recommend the employment of a man to act as secretary to the various national committees, and to perform such other functions as might properly be determined. Upon motion properly made and unanimously carried, this report was accepted and it was decided to employ such a man. President Burgess then appointed the following committee with full power to act: Messrs. W. H. Eisenman, W. S. Bidle and Dr. Zay Jeffries.

No definite appointments were made by the President for members on the Recommended Practice committee, with the exception of the appointment of J. Fletcher Harper as chairman.

It was moved and unanimously carried that a digest of the meeting of the Board should be published in the first following issue of TRANSACTIONS, and also that the chairman of the Finance committee should prepare a quarterly unaudited statement for publication in TRANSACTIONS in order that the membership may be thoroughly conversant with the work of the Board of Directors, as well as the financial condition of the society.

It was moved and unanimously carried that the following resolution be adopted:

> "RESOLVED, that we hereby acknowledge the members of the Society hereinafter named, as authorized to handle the banking affairs and to deposit and withdraw moneys from whatever bank

the Finance committee may designate upon checks signed by any two members of three names hereafter given. It shall be necessary, however, that one signature of the two names on the checks to withdraw must be that of the treasurer or secretary. The names of members authorized to sign checks for withdrawal or deposit are Dr. Zay Jeffries, national treasurer; W. H. Eisenman, national secretary; and J. V. Emmons, member of the Finance committee."

It was moved and unanimously carried that the bonds of the secretary and treasurer for $25,000 each, be continued, and that the members of the Finance committee authorized to sign checks should be bonded for $2500 each; the bonds to continue in the custody of the President.

The following resolution was presented, and upon motion properly made and carried, it was adopted:

"Recognizing the universal need for a set of generally accepted Heat Treatment Definitions, the directors of the A. S. S. T. do hereby RESOLVE: that the adoption of heat treatment definitions properly belongs to and should be fathered by the American Society for Steel Treating, and that the Recommended Practice committee is hereby directed to take this matter actively in hand."

The secretary then gave a report with reference to the progress of the data sheets and informed the Board that the first installment of this material would be mailed about the first week in December. The Board further authorized the secretary to place the name of the member of the Society on the binder when such binders were purchased through the national office.

A wire was received from Colonel A. E. White conveying his kind wishes and greetings. The secretary was authorized to send the following wire to the Colonel:

"The Board of Directors at their regular meeting in Washington express appreciation for the receipt of your wire, and extend to you kind greetings. They realize the great contribution you have made to the progress of the Society, and note with regret your first absence from the meetings of the Board."

It was moved and unanimously carried that the Board authorize the Secretary to write a letter of appreciation to J. V. Emmons for his services as treasurer. The letter is as follows:

My dear Mr. Emmons:

I have been authorized by the Board of Directors at their

regular meeting in Washington on November 2nd, 1923, to express their great appreciation for the valuable services you have given the society as national treasurer during the past two years.

They are conscious of the untiring effort and careful thought you have given to the duties of your office and the financial standing of the society at the present time is due, in no small part, to your eminent services.

They realize how impossible it is to adequately express their appreciation by written words, but they do sincerely wish you to know that as officers and directors of the society, representing the members, your aid in the advancement of the society will always be considered of the highest merit.

Yours very truly,
(Signed) W. H. EISENMAN.
National Secretary.

S. M. Havens, chairman of the Constitution and By-Laws committee submitted a tentative report of progress in making changes in the new constitution as recommended by the members at the last annual meeting. This report was accepted as a report of progress.

Requests were received from the Los Angeles chapter for a national officer to visit their chapter some time during the winter, and at the same time organize chapters of the society in San Francisco, Portland and Seattle.

A communication was also received suggesting the advisability of sending an A. S. S. T. representative to England during the next spring in order to make an intensive study of English technical societies as well as to attend the meetings of the Institute of Metals, the British Iron and Steel Institute, and also the British Empire's Industrial Exposition.

Upon motion properly made and unanimously carried, the secretary was instructed to secure estimates of the cost of the suggested trips and report at the next meeting of the Board.

In order to comply with the laws of Ohio in which the directors of the society elect their own officers, it was moved and unanimously carried that the individuals as indicated by the members as their choice for officers should be the officers and directors of the Board.

The meeting adjourned at 5:30 p. m.

CHARACTERISTICS OF SOME MANGANESE STEELS

By Jerome Strauss

Abstract

This paper consists in part of a review of previously published data on manganese steels and in part of a new metallographic survey (supplemented by mechanical tests) of a portion of the iron-carbon-manganese system.

Following a brief history of the development of iron-manganese alloys, an account is given of those manganese steels that have found commercial application. Their mechanical, electrical and magnetic properties are briefly considered.

The relation of microstructure to mechanical properties in a series of steels prepared in an induction furnace, forms the basis for a discussion of the constitution of these alloys and of possible improvements in some of the commercial combinations. In conclusion, directions in which manganese may prove useful as an alloying element, are indicated.

Introduction

THE history of modern alloy steel development begins with Sir Robert A. Hadfield's researches into the effect of large additions of ferromanganese to soft steel. There had been previously some inquiry, of course, into the properties imparted by the introduction of manganese, nickel, chromium and other elements but these either were unsystematic, or were discontinued (at least in the case of manganese) upon the first appearance of undesirable characteristics in the product, with increasing percentages of the added element. Credit must, therefore, be given Hadfield for his broader vision. His pioneering where others saw merely useless expenditure of effort opened a field, which in the 40 years since the announcement of his success, has been widely settled yet cultivated only in scattered spots. Our knowledge of alloy steels is still in its infancy.

A paper presented, in part, before the Philadelphia chapter of the Society. The author, Jerome Strauss, is material engineer, United States Naval Gun Factory, Washington, D. C.

Returning to the specific question of manganese steels, we find perhaps the first mention of the nonmagnetic iron-manganese alloys by Rinman, who in 1774 observed that the white, brittle metal obtained by fusing equal parts of gray pig iron and manganese oxide was not attracted by a magnet. About 1830, David Mushet prepared alloys containing up to 30.0 per cent manganese using manganese oxide, iron oxide, cast iron, charcoal and fluxing agents. He also noted the failure of the high-manganese alloys to be attracted by a magnet but was apparently dealing with alloys too high in carbon to observe the facts disclosed by Hadfield's later work. Subsequent development in this sphere yielded one outstanding feature, namely the application of ferromanganese (first produced commercially in 1865) to the steels made by the Bessemer and Siemens processes, to provide materials that would bear hammering and rolling; this application resulted from the work of Robert Mushet. Earlier experimenters had made small additions of manganese ore to crucible steel but the relative importance of their discoveries is slight.

About 1875, the Terre Noire works in France experimented with increases in the manganese content of structural steels, exhibiting the results of these experiments at the Paris exposition in 1878. The steels made contained from 0.45 to 0.60 per cent carbon and 0.52 to 2.42 per cent manganese. It was stated that the 1.3 per cent and 2.0 per cent manganese alloys cracked on oil quenching and that the steel carrying 2.4 per cent of this element could not be hammered or rolled. Hadfield's experiments and later production of such steels suggest that these failures were due to unsuitable raw materials or manufacturing processes or both, rather than to composition (the company reported 0.06 to 0.07 per cent phosphorus present, with sulphur content not mentioned though probably low). At about the same time, two German producers experimented with manganese steels and as their results also appeared to confirm the detrimental effect of manganese above 2.0 to 3.0 per cent, the Terre Noire company discontinued its labors in this direction. It should be noted, however, that one of the German steel works made alloys up to 4.4 per cent manganese with 0.66 per cent carbon, by additions of crucible-melted ferromanganese to Bessemer steel and the other, by manufacture directly in the crucible, made steels up to 11.4 per cent manganese,

but with a carbon content of 2.42 per cent. This unfortunately high carbon, as will be shown later, probably accounts for the failure of this particular set of experiments.

Because of these and probably many unpublished failures, Hadfield's courage and success and his discovery of the toughening treatment for the high-manganese alloys, justify the recognition they have received. A few tensile tests selected from the results of his early work[1] are given in Table I. These values were obtained on 1-inch rolled or forged bars, turned to 3/4-inch diameter for a gage length of 8 inches, except as noted in the table. Among

Table I
Effect of Manganese and Carbon on the Tensile Properties of Steel

Bar No.	Composition C	Mn.	Condition as Tested	Tensile Strength lbs. per sq. in.	Elongation in 8 in. per cent
1	.20	.83	As Rolled	75000	31.5*
2	.40	2.30	As Rolled	126600	6.5*
3	.40	3.89	As Rolled	85100	0.5
4	.52	6.95	As Forged	56900	1.5
5	.52	6.95	Water Quenched	52000	1.6
6	.50	7.90	Oil Quenched	66700	7.0
7	.61	9.37	Air Cooled	84400	15.6
8	.61	9.37	Oil Quenched	85600	14.8
9	.61	9.37	Water Quenched	87100	14.8
10	.85	10.60	Air Cooled	91500	17.2
11	.85	10.60	Oil Quenched	94300	18.8
12	.85	10.60	Water Quenched	91600	17.2
13	.85	12.29	As Forged	88000	3.5
14	.85	12.29	Water Quenched	145000	50.0
15	1.10	12.60	As Forged	88000	2.3
16	1.10	12.60	Water Quenched	120600	27.3
17	.92	12.81	Air Cooled	108200	19.5
18	.92	12.81	Oil Quenched	129000	32.8
19	.92	12.81	Water Quenched	136200	36.7
20	.85	13.75	Water Quenched	145400	50.7
21	.85	13.75	Water Quenched, Reheated and slowly cooled	102600	6.2
22	.85	14.01	Air Cooled	107300	14.1
23	.85	14.01	Oil Quenched	123200	26.6
24	.85	14.01	Water Quenched	150300	44.4
25	1.10	14.48	Water Quenched	142000	37.5
26	1.55	14.16	Water Quenched	100400	14.1
27	1.24	15.06	Water Quenched	135600	31.2
28	1.54	18.40	As Forged	114700	0.8
29	1.54	18.40	Water Quenched	119200	10.1
30	1.60	19.10	As Forged	115400	0.8
31	1.60	19.10	Water Quenched	131100	4.6
32	2.10	21.69	As Forged	80600	8.6
33	2.10	21.69	Water Quenched	74600	10.9

Note:—All quenching and air cooling made from "white heat."
* Bars 1⅛-inch diameter between 10-inch gage marks.

the facts disclosed by these tests, the following are of particular interest and the reasons for some of them will be briefly indicated later:

(a) The increase in tensile strength and decrease in ductility

1. R. A. Hadfield—Manganese in its Application to Metallurgy and—Some Newly Discovered Properties of Iron and Manganese, *Proceedings* of Institution of Civil Engineers, 1887-1888.

with small increases in manganese and carbon and the subsequent decrease in both up to 0.5 per cent carbon and 7.0 per cent manganese.

(b) The increase in tensile strength and elongation of quenched bars, beginning at 0.5 per cent carbon and 8.0 per cent manganese and reaching a maximum between 12.0 and 15.0 per cent manganese.

(c) The uniformity of tensile properties in the 9.4 and 10.6 per cent manganese steels with various cooling rates after heating, provided such rates are fairly rapid (bars 7, 8, 9 and 10, 11, 12).

(d) The marked effect of rate of cooling after heating on the strength and ductility of the 12.8 and 14.0 per cent manganese steels (bars 17, 18, 19 and 22, 23, 24).

(e) The decrease in strength and elongation in the toughest steels with increases in carbon content (bars 14, 19, 16 and 24, 26, 25).

Commercial Manganese Steels

(*a*) *Low Manganese Steels*

Due, probably in part, to failures of early Bessemer rail steels containing over 1.0 per cent manganese and to Hadfield's original statement that with 2.5 to 7.5 per cent, the resultant steels were unfit for commercial application, but undoubtedly more directly due to sad experiences in attempting to apply drastic quenching to eutectoid steels having slightly more than normal amounts of this element, there has grown upon most practical men a distrust of all steels containing 1 per cent or more. Because water quenching will often crack eutectoid steels of such composition is not sufficient cause for maintaining that steels of 1.0 to 2.0 per cent manganese are brittle; the possibility of the heat-treatment given not being suited to the steel, structural inequalities due to previous mechanical and thermal treatment and defects traceable to steel-making processes must also be considered. The suitability of the heat treatment is of particular importance and is equally applicable to the present case as to other tender alloy steels. In fact 1.0 to 2.0 per cent manganese, while increasing the strength and hardness of the carbon steels, and in some cases rendering them sensitive in heat treatment does not impart brittleness and should not limit their commercial use.

In the realm of very soft steels, the work of Lang[2] is of considerable interest and some of his mechanical tests are listed in Table II. Although the author did not describe his manipulations in detail and used steels of varying phosphorus content (0.04 to 0.11 per cent) and clearly indicated the absence of pyrometric control in his heat treatments, the results, nevertheless, have much value. In the rolled or annealed bars there is a marked increase in proportional limit and tensile strength without appreciable loss in ductility or notched-bar impact resistance up to 1.77 per cent manganese. After quenching, the same is true up to 1.27 per

Table II

Mechanical Properties of Low Carbon Manganese Steels

Series	Steel No.	Composition C	Composition Mn	Prop. Limit lbs. sq. in.	Tensile Strength lbs. sq. in.	Elongation % in 8″	Reduction of Area %	Brinell	Impact ft. lbs. sq. in.
A— As Rolled	1	.11	.29	46000	62600	27.9	53.5	11	1100
	4	.10	.79	49200	64500	27.9	65.9	119	1580
	6	.10	1.27	54300	71300	27.9	68.1	132	1250
	8	.10	1.77	57900	82500	25.9	54.7	156	1190
	11	.09	2.47	63400	103000	18.8	39.4	211	130
B— Annealed	1	.11	.29	43200	56900	31.5	70.0	113	1460
	4	.10	.79	45100	59700	30.3	70.1	118	1520
	6	.10	1.27	46600	65000	30.2	72.6	132	2050
	8	.10	1.77	48300	73900	27.4	72.3	159	1970
	11	.09	2.47	52300	108200	15.4	53.1	218	660
C— Quenched	1	.11	.29	42900	78700	19.6	61.0	147	1120
	4	.10	.79	49600	85000	14.1	56.1	157	1420
	6	.10	1.27	61600	107900	15.2	48.2	230	870
	8	.10	1.77	86000	155000	9.0	44.6	273	700
	11	.09	2.47	92200	166600	3.1	18.9	...	550

cent and would probably hold good up to a higher percentage, were slight drawing resorted to. Also the relative increase in strength due to quenching is very much greater with the higher manganese proportions.

Thus, to some extent, manganese can replace carbon in increasing the strength of plain steels and this principle has found frequent application; there is usually an appreciable increase in ductility. In general, it would appear desirable in soft steels to obtain the increased strength in untreated parts by an increase in carbon, but to use manganese where the steels were to be applied in the heat-treated state.

These 1.0 to 2.0 per cent manganese steels of low carbon content are not, however, suitable where good magnetic or electrical

2. G. Lang—Uber den Einfluss des Mangans auf die Eigenschaften des Flusseisens—*Metallurgie*, 1911.

properties are desired. Lang's steels, with the 2.2 per cent manganese increase, showed a gradual rise in electrical resistance totaling over 60 per cent (independent of heat treatment), and an increase in both coercive force and hysteresis, which in the quenched series amounted to 330 and 140 per cent respectively; simultaneously the permeability was appreciably lowered.

Several years ago, Abbott[3] published the results of some experiments with a structural steel containing a relatively high proportion of manganese; some of his results, grouped in Table III, are worthy of close study. In the annealed condition the man-

Table III

Comparison of Physical Properties of Carbon, Nickel and Manganese Steels

Chemical Analysis

	C	Si	S	P	Mn	Ni	Cu
Carbon	.34	.030	.029	.014	.54	....	
Nickel	.34	.188	.019	.019	.55	3.17	.05
Manganese	.34	.009	.025	.047	1.61	....	.02

Tensile Properties

	Elastic Limit	Tensile Strength	Elongation in 2"	Reduction Area	Brinell	Heat Treatment
Carbon	36600	67250	32.0	51.0	120	Annealed
Nickel	55000	81850	31.2	59.0	153	
Manganese	61150	87850	29.9	58.5	150	
Carbon	72000	110000	18.0	50.0	192	Water
Nickel	147000	152000	17.5	60.0	243	Quenched
Manganese	153000	158000	15.5	44.5	250	Drawn 800°F
Carbon	64000	93000	23.5	60.5	163	Water
Nickel	115000	120000	22.0	65.0	207	Quenched
Manganese	118000	126000	18.0	50.5	214	Drawn 1000°F
Carbon	59000	78000	29.0	68.0	152	Water
Nickel	88000	95000	28.5	68.5	158	Quenched
Manganese	91000	96000	23.0	58.5	172	Drawn 1200°F

ganese steel is far superior to the carbon steel and possesses an elastic limit and a tensile strength somewhat greater than those of the nickel steel, along with equal hardness and very slightly lower ductility. After water quenching and drawing (holding 30 minutes) the manganese steel still possesses for the same drawing temperature, an advantage over the nickel steel in elastic limit and tensile strength, although the ductility of the former material is somewhat lower. Tests of oil-quenched bars as well as data on notched-bar toughness and resistance offered to alternating stresses would have greatly increased the interest that attaches to these figures. There has been some commercial use of small forgings of this composition and of plates with somewhat lower carbon con-

3. R. R. Abbott—A Comparison of the Properties of a Nickel, Carbon and Manganese Steel Before and After Heat Treatment, *Transactions*, American Society of Mechanical Engineers, 1915.

tent but not to the extent which the author considers economically desirable from a consideration of these and other tests. To mention specific uses, steels of 0.25 to 0.35 per cent carbon and 1.10 to 1.40 per cent manganese have at times been used to replace 0.35 to 0.45 per cent carbon steels with normal manganese, in drop forgings for automotive and similar service. Sheets of the same or higher manganese, but lower carbon content have been used for motor car and also railway construction but this particular application has been almost entirely confined to European countries.

A 0.50 per cent carbon steel containing over 1.20 per cent manganese has been reported [4] as having been satisfactorily employed for small arms rifle barrels and is still in use. It may be of value to call attention to Bellis' findings in comparing this steel with one of similar carbon content but with normal manganese (0.65 per cent). It appears that, in heat-treated parts of small cross section, increasing the time at the drawing temperature, caused in both steels a 25 per cent increase in ductility, but accompanying it a 4 to 5 per cent drop in proportional limit and tensile strength for the normal steel, with but 1/2 per cent decrease in these values for the high-manganese steel; the latter value is, of course, less than the difference usually found in duplicate heat-treated bars. In the light of these tests, heat-treatment modification in the case of Abbott's steels might have been even more favorable to the high-manganese alloy. Steel of the same composition as used in these rifle barrels has found successful application for a number of years in cylinders for the transportation of various gases under high pressure.

In the direction of somewhat higher carbon contents, an outstanding example of the use of manganese above 1 per cent is in spring steels of about 0.60 per cent carbon and 1.15 per cent manganese. It has been contended by manufacturers and others that this material is not amenable to hardening by the user, and therefore, its major application has been as "tempered" wire in small diameters for springs for automobile and also general household upholstery. In spite of such contentions, the United States Navy has for a number of years used this steel up to 3/4-inch diameter for helical springs to carry maximum stresses intermediate between those for which carbon steel and those for which the more ex-

4. A. E. Bellis—Time Effect in Tempering Steel, *Transactions*, American Institute of Mining Engineers, 1918.

pensive and stronger alloy steels are used. This material has been made by either the acid or basic open-hearth process to a composition of carbon—0.55 to 0.65 per cent and manganese—1.00 to 1.25 per cent. After oil quenching and drawing these springs have successfully withstood all service stresses for which they were designed as well as those rigorous inspection tests applied to gun recoil springs, such as clamping solid for periods up to 48 hours and repeated rapid compression from free length to almost solid length 100 or more times; in the latter test a steam hammer has been used for load application.

In the eutectoid range, steels of 0.80 to 0.95 per cent carbon with manganese 1.00 to 1.75 per cent and with or without small additions of vanadium or tungsten and chromium have been unusually successful for intricate dies and other cutting tools and also gages where a combination of hardness and freedom from appreciable dimensional changes in heat treatment is necessary. Given correct forging and avoidance of careless heat application in treatment, there is no danger of cracking in oil-hardening these steels and, though not generally recommended, water-quenching is frequently successfully practiced.

Some years ago the author found that a steel of 0.80 per cent carbon and 2.00 per cent manganese was particularly suitable for use as shear blades in cold cutting of steel bars, having a greater service life under similar conditions than any carbon steel tried or chrome-vánadium steel of equal carbon content. No difficulty was experienced in hardening blades of this material even in masses weighing 500 pounds.

Apart from these forged or rolled materials, there has been frequent mention in the literature of steel castings containing manganese in excess of 1.0 per cent. Prominent among these is the report of Hall, Nissen and Taylor(5) giving a summary of tests taken from several years' production of castings of this composition. Most of the steel castings to which these authors refer were water quenched and then drawn at temperatures of 1150 degrees Fahr., or higher. Comparisons of steels of about 0.22 per cent carbon and 1.0 to 1.5 per cent manganese with 0.50 per cent carbon steels containing about 0.65 per cent manganese show for

5. J. H. Hall, A. E. Nissen and K. Taylor—Heat Treatment of Cast Steel, *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol LXII (1920), page 353.

equal tensile strength (80,000 to 85,000 pounds per square inch) an approximate increase of 15 per cent in elastic limit, 25 per cent in elongation and over 100 per cent in reduction of area; impact resistance by the Fremont method, although varying widely according to the manganese content, was two to four times as great. Some remarkable results were also given for a cast Bessemer steel containing 0.36 per cent carbon and 2.42 per cent manganese; with 25 per cent additional tensile strength the shock resistance equalled that of the 0.50 per cent carbon steel to which reference has just been made.

(*b*) *High Manganese Steels*

Ternary steels containing from 3.0 to 7.0 per cent of manganese have found no commercial application and with the higher proportions are not likely to be widely used as long as present manufacturing limitations, which enforce a minimum carbon content for any desired manganese percentage, must continue. Beginning, however, with 8.0 per cent and from this up to 16.0 per cent of manganese, steels have been prepared and very extensively used, both as castings and forgings, which possess a number of peculiar and interesting properties. These are the steels which were developed by Hadfield's researches and have since been known under the single term "Hadfield's manganese steel" or more commonly "manganese steel." Although the variation of manganese over this broad range along with the necessary (and sometimes undesirable) carbon variations, produce alloys of somewhat different properties, these effects will be discussed later, leaving for immediate attention only those generally characteristic of the entire group.

Many of the peculiar properties of these alloys are explained by two metallographic features, namely (a) their 100 per cent austenitic constitution when properly heated and quenched and (b) the precipitation of dark-etching acicular constituents under certain conditions of composition and thermal treatment. To the first condition is due the absence of magnetism, the moderate hardness, the high tensile strength, the high ductility and the low elastic ratio. These properties "manganese steel" possesses in common with the austenitic nickel steels and most other single-phase solid-solution alloys. Under the influence of cold work, however, it hardens

more readily than any of these alloys and it is this peculiarity which has caused its application wherever extreme resistance to wear was a prime requisite and slight surface flow with the accompanying dimensional change prior to obtaining effective wear resistance, was not a drawback. This same property has, however, limited its use inasmuch as the hard surface produced by abrasion

Table IV
Quenching Tests of High Manganese Steel
Carbon Content 1.10-1.15 *per cent*
Manganese Content 11.00-11.50 *per cent*
⅝" diameter. Bars heated to 1700°F. cooled at the rate of 100°F per hour, and quenched in water from the temperature indicated

Test No.	Temperature Degrees Fahr.	Elongation Per Cent	Breaking Stress lbs. sq. in.
1	1700	51.6	153800
2	1650	56.7	156700
3	1600	61.2	153950
4	1550	64.2	153200
5	1500	44.8	137200
6	1450	31.0	120450
7	1400	15.1	93370
8	1350	15.7	88750
9	1300	10.5	84120
10	1250	7.8	78060
11	1200	4.6	73950
12	1150	4.5	76940
13	1100	4.5	78040
14	1050	3.1	71220
15	1000	2.7	71625
16	950	1.5	68070
17	900	1.4	74440
18	850	1.5	80000
19	800	1.2	75290
20	750	0.5	69570
21	700	0.8	72500

develops also in most machining operations so that although it can be cut[6] such procedure is decidedly uneconomical. It was the ease of indentation (the Brinell hardness averages about 200) combined with the development of this surface condition that led Hadfield to describe the steel as possessing a "peculiar hardness" combined with "a special kind of softness." This extreme ductility and softness is such that, unlike the behavior of most steels, cracks once started in austenitic manganese steel of about 12.0 per cent manganese are propagated only with great difficulty, even under impact.

The second structural condition noted above is responsible for the extreme brittleness of these alloys when cooled slowly from a high temperature and the brittleness induced by heating to relatively low temperatures as well as the difficulty of obtaining a ductile

6. Machining is rendered somewhat easier by the use of liquid mixtures or solutions possessing great cooling ability as well as lubricating qualities or by certain heat treatments, the effects of which must be removed after machining is completed.

metal of small grain size with certain chemical compositions. The temperatures at which the sharp changes in tensile properties occur and the values that may be expected from rolled high-manganese steel have been clearly shown by Potter,[7] some of whose results are reproduced in Tables IV and V. In the series of bars quenched from successively lower temperatures the lowering of the tensile

Table V
Quenching Tests of High Manganese Steel
Carbon Content 1.10-1.15 *per cent*
Manganese Content 11.00-11.50 *per cent*
[illegible]" diameter bars heated for sixty minutes at the temperature indicated and quenched in water.

Test No.	Temperature Degrees Fahr.	Elongation Per Cent	Breaking Stress lbs. sq. in.
1	500	57.6	166500
2	500	53.0	169300
5	600	63.5	176000
6	600	55.0	163100
7	650	15.6	128000
8	650	21.7	137700
9	700	3.6	138200
10	700	1.6	116300
41	1500	23.5	139000
42	1500	26.7	142600
43	1550	57.4	155500
44	1550	52.8	154300
45	1600	42.4	162900
46	1600	42.5	161200
47	1650	65.0	147800
48	1650	63.8	145900
49	1700	62.1	143200
50	1700	58.9	139400
53	1800	56.5	133400
54	1800	53.2	132100
55	1900	44.1	123700
56	1900	42.0	121200
59	2100	35.7	93200
60	2100	40.9	99200
61	2200	17.3	80600
62	2200	21.7	79200

values takes place shortly after passing 1550 degrees Fahr. In the series quenched from successively higher temperatures, maximum strength and ductility are obtained at this same temperature. This temperature would regulate the conditions of rolling, if the resultant product were finished by quenching after the last pass. In Table V, the decrease in tensile values on reheating above 600 degrees Fahr. would indicate this as a maximum temperature for such operations as shrinking of forgings or castings on shafts, bushings, etc. The progressive decrease in strength above 1600 degrees Fahr. and in ductility above 1700 degrees Fahr. also indicate the undesirability of heating to too high a temperature for quenching; nevertheless, temperatures considerably above these have been advocated by some manufacturers. Furthermore, not only

7. W. S. Potter—Manganese Steel with Especial Reference to the Relation of Physical Properties to Microstructure and Critical Ranges. *Transactions*, American Institute of Mining Engineers, 1914.

quenching from a high temperature but also quenching from the proper temperature after cooling from the high temperature, results in poor tensile properties. Potter[8] found that cooling 3/4-inch diameter bars from 2100 degrees Fahr. at 100 degrees Fahr. per hour to various temperatures, followed by water quenching, yielded low strength and ductility at any quenching temperature, the values at 1600 degrees Fahr. being 79,510 pounds per square inch tensile strength and 25.4 per cent elongation. Similar behavior has been found in most other steels.

The combination of high tensile strength and high elongation in those steels of Tables IV and V that are in their best structural condition, is most unusual. In the use of certain so-called "merit-values" which involve the product of the tensile strength and elongation in fixing the order of superiority of structural metals, the author knows of no material that would excel "manganese steel." These values are not unusual for bar stock of relatively small size, and test bars taken from the head of heavy rails, which frequently are not quenched from the optimum temperature, commonly give values of 125,000 pounds per square inch tensile strength with 30 per cent elongation in two inches although ordered to a specification of 100,000 pounds per square inch and 20 per cent elongation.

As previously noted there are many points of similarity in the characteristics of the austenitic manganese and the austenitic nickel steels. But there are many differences, among which may be briefly mentioned the fact that the nickel steels possess marked resistance to many corroding influences whereas the resistance of the high manganese alloys is only slightly greater than that of carbon steel. The more interesting contrasts are in the hardness and magnetic properties as affected by various degrees of cold-working and by temperature changes. The surface hardening of "manganese steel" by abrasion has already been mentioned. In the progress of a tensile test, severe cold-working occurs, and in the case of "manganese steel," a Brinell hardness increase from 223 to 540 at the point of rupture, has been recorded.[9] The same authors observed for high-nickel steel a maximum change

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8. Loc. Cit.

9. R. A. Hadfield and B. Hopkinson—the Magnetic and Mechanical Properties of Manganese Steel, *Journal* of the Iron and Steel Institute, 1914, and Researches with Regard to the Non-Magnetic and Magnetic Conditions of Manganese Steel, *Transactions*, American Institute of Mining Engineers, 1914.

of from 180 to 340. Accompanying this hardness was the development of a distinct magnetic condition in the nickel steel, although the hardened manganese steel showed only a mere trace of magnetism.

On heating at certain moderate temperatures "manganese steel" shows, with increasing time and temperature, an increase in hardness and also the presence of considerable magnetism. These changes, however, do not parallel one another. According to Hadfield and Hopkinson[10] high hardness (above 350 Brinell) becomes evident after several hours exposure at 750 degrees Fahr., whereas moderate magnetism is not obtained until similar exposures at 930 degrees Fahr. are used. A maximum hardness of 495 was obtained after 48 hours at 1020 degrees Fahr. and maximum magnetism after 600 hours at 930 degrees Fahr. Along with the magnetic effects is found a decided decrease in the difficulty of machining. It is also noteworthy that the magnetic qualities obtained in the above manner, practically disappear after one hour of heating at 1380 degrees Fahr. Such changes did not occur in high-nickel steels with heating periods up to 96 hours between 570 and 1290 degrees Fahr. Long exposure to liquid air temperature produced no appreciable hardness change and no magnetic effects in the manganese steel, whereas such temperature caused in the nickel steel, a very decided increase in the specific magnetism with a definite, though small increase in hardness (180 to 250, of which about 25 may have been due to the change of temperature alone, exclusive of structural changes).

In the manufacture of "manganese steel" it has been observed that the metal, as poured, is very fluid, (its melting range is about 2300 to 2450 degrees Fahr.) being more like cast iron than steel, and that it sets quickly, but with considerable liquid-to-solid contraction. In fact, the high losses due to piping of this metal were a strong factor in the development of the modern inverted, hot-top ingot mold. Another important property, from the producer's viewpoint, is the low thermal conductivity. This has enforced unusual care in maintaining soaking pit temperatures, at time of charging, close to that of the incoming ingot and also in insuring thorough soaking at the rolling temperature (2100 to 2150 degrees Fahr.) to avoid serious loss through ingots breaking in the blooming mill.

10. Loc. Cit.

Further, it has limited the thickness of the walls of castings to about 6 inches due to the difficulty of obtaining a satisfactory quenching effect in thicker sections.

It should be mentioned that these high manganese steels have a low electrical conductivity as well as a low thermal conductivity. Completely austenitic alloys of 1.0 per cent carbon and 12.0 to 14.0 per cent manganese offer a resistance to the flow of an electric current approximately 30 times as great as that of copper. On this account these alloys, soon after their discovery, were used in the form of resistance wire but the high temperature coefficient of electrical resistance combined with drawing difficulties due to rapid wearing of dies, prevented widespread use for this purpose.

Microstructure and Mechanical Properties

To illustrate the structural characteristics of a series of steels with increasing carbon and manganese contents and demonstrate the relationship of microstructure to mechanical properties a series of small ingots were prepared and subjected to a number of tests. The steels for these ingots were melted in an Ajax-Northrup high-frequency furnace, the charge being made up of Armco iron, crucible-melted carbon tool steel, carbon-free manganese, high-grade 80 per cent ferromanganese and washed metal in the proportions necessary to produce ingots of the desired composition. The raw materials were melted in an open crucible and as soon as completely molten and thoroughly agitated by the action of the induced current, were poured into cast-iron molds. The resulting ingots, approximately 1 1/4 inches square and 7 inches long were cut transversely into two equal lengths; this was just sufficient to avoid the pipe in the lower portion, in those ingots having the

Table VI
Chemical Analysis of Manganese Steel Ingots

Ingot	Chemical Composition				
No.	C	Si	S	P	Mn
469	.03	.11	.027	.003	5.88
470	.04	.16	.027	.007	8.61
630	.05	.38	.034	.009	16.35
444	.45	.05	.035	.015	3.58
443	.48	.08	.039	.025	8.72
442	.46	.10	.041	.018	14.39
449	.78	.16	.022	.019	1.86
448	.78	.18	.032	.017	4.40
446	.81	.22	.024	.013	8.87
450	.94	.14	.030	.015	12.68
445	1.20	.31	.020	.028	4.62
447	1.27	.19	.020	.016	8.68
632	1.22	.30	.029	.017	12.40
631	1.85	.18	.042	.013	4.26

Table VII

Tensile Properties of Forged Manganese Steels

Bar No.	Ingot No.	Composition C	Composition Mn.	Heat Treatment (deg. Fahr.) Anneal	Heat Treatment (deg. Fahr.) Quench	Draw	Prop. Limit lbs. per sq. in.	Tensile Strength lbs. per sq. in.	Elong. per cent	Reduction of Area per cent	Fracture
X-2	469	.03	5.88	1700 fce. cool	....	....	65080	115000	1.3	1.3	Sq. Silky Large Crack
X-1	469	.03	5.88	1700 fce. cool	1750 Water	....	87700	143400	12.1	42.0	Ang. Crack
X-4	470	.04	8.61	1700 fce. cool	....	....	87700	150600	1.7	2.6	Sq. Fine Gran.
X-3	470	.04	8.61	1700 fce. cool	1750 Water	....	99030	152800	2.0	3.3	Sq. Gran.
X-30	630	.05	16.35	1700 fce. cool	....	....	28300	104500	16.6	13.5	Sq. Gran.
X-31	630	.05	16.35	1700 fce. cool	1750 Water	....	34000	119500	40.0	49.5	.6 Cup
X-10	444	.45	3.58	1600 fce. cool	....	....	62200	123000	20.4	44.3	Ang.
X-9	444	.45	3.58	1600 fce. cool	1500 Oil	1100 Air	135800	157000	17.0	46.6	Star
X-8	443	.48	8.72	1600 fce. cool	....	....	39000	128000	1.7	2.6	Sq. Gran. & Fib.
X-7	443	.48	8.72	1600 fce. cool	1650 Water	....	37000	74000	1.7	2.0	Sq. Gran.
X-6	442	.46	14.39	1600 fce. cool	....	....	31100	101100	16.3	19.0	Sq. Gran.
X-5	442	.46	14.39	1600 fce. cool	1650 Water	....	31100	109600	18.3	22.6	Sq. Fine Gran.
X-20	449	.78	1.86	1600 fce. cool	....	....	53750	128700	10.8	13.5	Sq. Gran.
X-19	449	.78	1.86	1600 fce. cool	1450 Oil	1100 Air	144300	170 00	14.2	33.3	Sq. Silky .6 Cup
X-18	448	.78	4.40	1600 fce. cool	....	....	59400	139300	5.4	6.6	Sq. Fine Gran.
X-17	448	.78	4.40	1600 fce. cool	1450 Oil	1100 Air	127300	178000	3.3	4.0	Sq. Fib.
X-14	446	.81	8.87	1600 fce. cool	....	....	79200	163500	1.1	6.7	Broke in Thds.
X-13	446	.81	8.87	1600 fce. cool	1650 Water	....	42400	92600	12.1	20.2	Sq. Silky
X-22	450	.94	12.68	1600 fce. cool	....	....	34000	111700	1.7	2.7	Sq. Gran. & Fib.
X-21	450	.94	12.68	1600 fce. cool	1650 Water	....	45200	145700	47.1	39.2	Ang.
X-23	445	1.20	4.62	1600 fce. cool	....	....	53750	129400	4.6	5.3	Sq. Silky
X-11	445	1.20	4.62	1600 fce. cool	1650 Water	....	42400	67200	3.3	8.5	Sq. Fine Gran.
X-12	445	1.20	4.62	1600 fce. cool	1650 Oil 1400 Oil	1100 Air	121500	169500	2.9	2.6	Sq. Star
X-16	447	1.27	8.68	1600 fce. cool	....	....	96100	175400	1.3	1.3	Sq. Silky
X-15	447	1.27	8.68	1600 fce. cool	1650 Water	....	45300	96300	7.9	14.1	Sq. Fine Gran.
X-32	632	1.22	12.40	1600 fce. cool	....	....	36800	128700	3.7	3.3	*Sq. Silky
X-33	632	1.22	12.40	1600 fce. cool	1650 Water	....	53750	137000	20.0	22.5	*.6 Cup
X-34	631	1.85	4.26	1600 fce. cool	1650 Water	....	48000	87750	3.3	5.2	*Sq. Gran.
X-35	631	1.85	4.26	1600 fce. cool	1980 Air 1650 Water	....	48000	96750	3.3	3.9	*Sq. Gran.

* Broke in Points.

greatest pipe depth. A slice 1/2 inch thick was taken from the lower end of the upper half and samples cut from it for the study of the microstructure in the cast state. The lower half was forged to a 3/4-inch octagonal bar and short lengths from this used for microscopic examination after which the remainder was forged to 1/2-inch diameter and cut into tensile test specimens.

Heat treatments were all performed in an electrically heated muffle furnace, both microscopic specimens and tensile bars being maintained at the annealing or quenching temperature for 15 minutes, and at the drawing temperature for 30 minutes. Microscopic examination of the cast metal was on surfaces transverse to the

Table VIII
Brinell Hardness of Manganese Steels

Ingot	Composition		Cast				Forged			
No.	C.	Mn.	As Cast	Annealed	Quenched	Q. & Drawn	As Forged	Annealed	Quenched	Q. & Drawn
469	.03	5.88	277	207	302	196	269	248	286	207
470	.04	8.61	293	321	311	255	286	302	302	241
630	.05	16.35	196	196	207	217	241	196	1[illegible]6	217
444	.45	3.58	286	228	460	311	512	228	512	293
443	.48	8.72	332	340	321	375	302	3[illegible]0	321	3[illegible]4
442	.46	14.39	217	196	207	217	255	212	223	21[illegible]
449	.78	1.86	302	241	555	311	286	241	652	31[illegible]
448	.78	4.40	302	269	460	340	302	255	477	34[illegible]
446	.81	8.87	163	418	187	444	387	387	196	477
450	.94	12.68	166	269	187	217	217	321	187	202
445	1.20	4.62	351	269	187	364	444	269	187	364
447	1.27	8.68	212	444	217	477	241	418	226	477
632	1.22	12.40	255	364	255	361	269	364	241	340
631	1.85	4.26	444	364	286	387	512	340	255	387

axis of the ingot and of the forged bars on surfaces parallel to the direction of forging. After photographing, these same surfaces were used in making the Brinell hardness determinations, all such tests being obtained with the 3000-kilogram load. The Brinell values are given in Table VIII. The tensile bars, 1/2-inch diameter, when heat-treated, were ground to 0.30 inch in the 2.20-inch pulling section; the 1/2-inch threaded ends were turned or ground. The proportional limit was determined by extensometer on a 2-inch gage length, but in computing elongations, a gage length equal to four times the diameter was used; such lengths had been marked prior to testing at several locations along the pulling section. The results of these tensile tests are given in Table VII.

The constitutional diagram of the carbon-manganese steels, as determined by Guillet,[11] for forged and air-cooled samples is shown in Fig. I. It will be observed that for very low carbon

11. L. Guillet—Etude Industrielle des Alliages Metalliques, Paris, 1906.

contents, the steels are pearlitic up to 5.0 per cent manganese, and the same in the case of 1.0 per cent carbon and up to 2.0 per cent manganese; also that with very low carbon, 13.0 per cent of manganese or with 1.0 per cent carbon, about 6.0 per cent of manganese renders the alloy austenitic; further, that above 1.0 per cent carbon, steels of the intermediate range contain no martensite.

The first alloy of the series, ingot 469, is in Guillet's transition zone; the structures produced by various heat treatments are shown

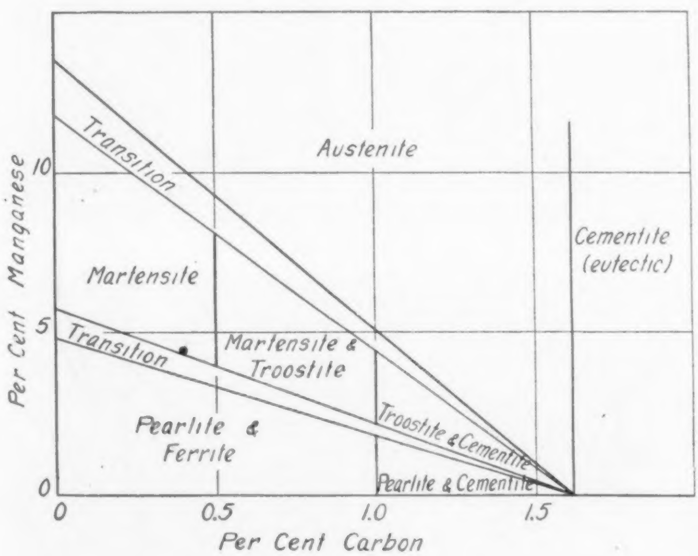

Fig. 1—Structure of Forged and air-cooled Manganese Steels.

in Fig. 2. The untreated and quenched specimens are decidedly martensitic in structure; after drawing, this acicular structure is still present, though less prominent, (some small areas in Fig. 2(h) resemble troostite) while after annealing the appearance of the etched samples is similar to that of a fine-grained iron. Unfortunately this one ingot had a very poor surface, the defects being deeper than first appreciated; this has detracted from the value of the tensile tests, both of the bars showing longitudinal cracks at the fracture; rupture was premature in each case. On a steel of similar composition, Arnold and Knowles,[12] reported a tensile

12. *Engineering*, Vol. 92, page 478.

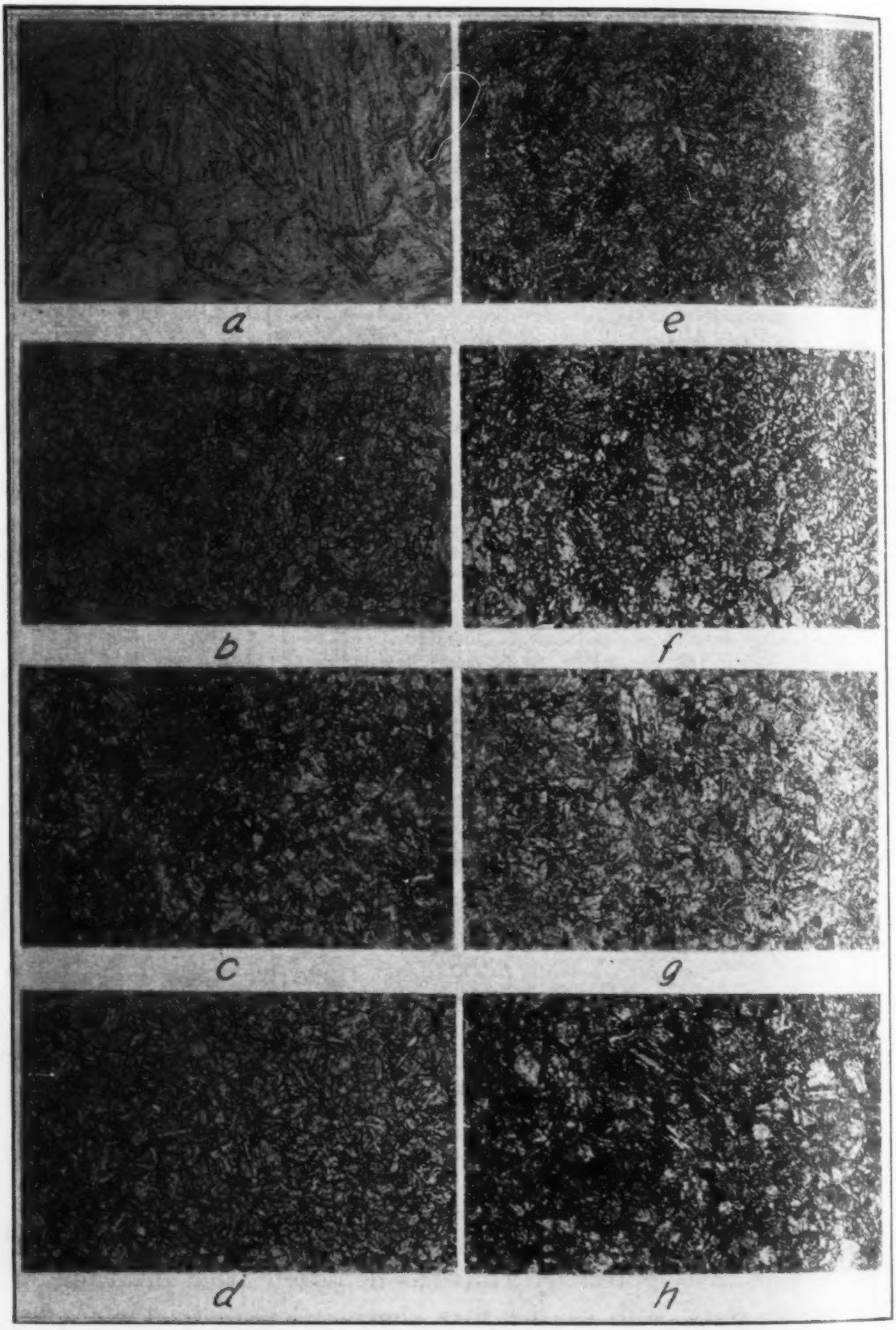

Fig. 2—Carbon, 0.03 per cent; manganese, 5.88 per cent. All magnifications x 100. (a), (b), (c), (d) cast; (e), (f), (g), (h) forged. (a) as cast; (e) as forged; (b) and (f) 1700 degrees Fahr. (15 min.) furnace cooled; (c) and (g) 1750 degrees Fahr. (15 min.) water quenched; (d) and (h) 1750 degrees Fahr. (15 min.) water cooled, 1100 degrees Fahr. (30 min.) cooled in air.

strength of 147,000 pounds per square inch with an elongation of 28.5 per cent after a very slow anneal (three-day cooling period); they also found that the resistance to alternating stress was good in the annealed state but very poor after quenching. In the present instance it is believed that sound bars would have shown comparable values, but it is also probable that alternating stress tests would have been more favorable to quenched samples of the authors' steel, if it is possible to judge of this from the tensile and hardness data.

The microstructure of the low carbon 9.0 per cent manganese steel is shown in Fig. 3. Martensite is the predominating constituent although photographs (a) and (c) give the appearance of some austenite while the annealed and the quenched and drawn specimens show areas similar in appearance to troostite. The reason for the existence of the austenite is apparent and is supported by the hardness determinations, but the explanation of the presence of troostite is not clear, unless perhaps due to areas low in manganese resulting from the usual concentration variation during rapid solidification. These dendritic formations have persisted through the heat treatments in most of the cast specimens and at times in the forged ones also. This interpretation does not account for the hardness of the quenched and drawn specimens being less than that of any others but does satisfactorily explain the increase in proportional limit on quenching an annealed bar.

The 16.0 per cent manganese low-carbon alloy (Fig. 4) shows in the cast form a very decided dendritic structure which has persisted through the forging operation to a greater degree than in the case of any of the alloys prepared. The matrix in each case is austenitic, the dendrites being a low-carbon martensite due undoubtedly to manganese segregation occurring during freezing of the molten metal. Long soaking at moderately high temperature would be required to efface this heterogeneity. The physical tests show the usual characteristics of an austenitic structure—low hardness, low proportional limit, relatively high tensile strength and considerable ductility.

In the microstructure of the medium-carbon 3.5 per cent manganese steel, there are no constituents that are not common. Nevertheless, it should be noted that with only 0.45 per cent carbon, this steel contains but very little free ferrite (the few small

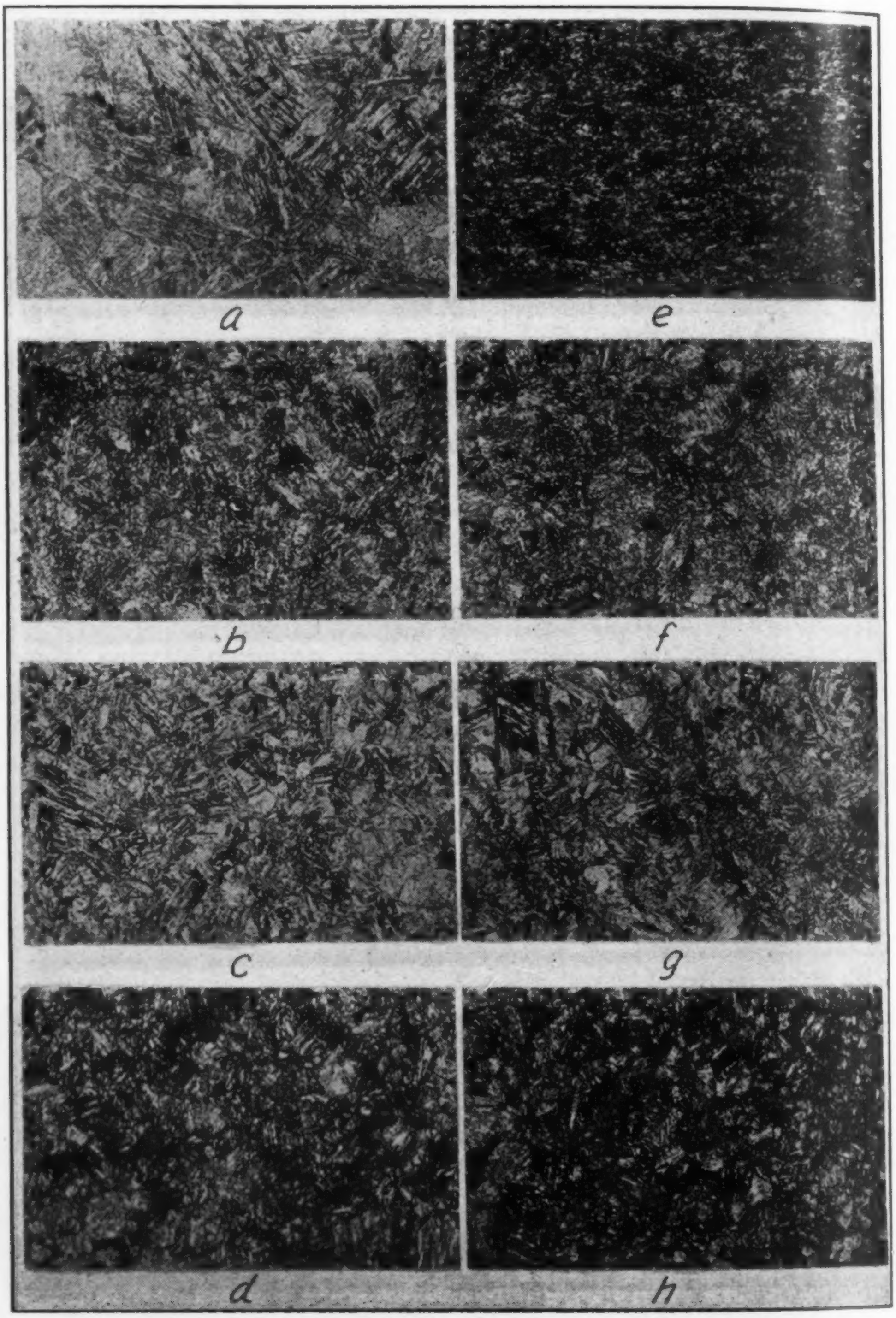

Fig. 3—Carbon, 0.04 per cent; manganese, 8.61 per cent. All magnifications x 100. (a), (b), (c), (d) cast; (e), (f), (g), (h) forged. (a) as cast; (e) as forged; (b) and (f) 1700 degrees Fahr. (15 min.) furnace cooled; (c) and (g) 1750 degrees Fahr. (15 min.) water quenched; (d) and (h) 1750 degrees Fahr. (15 min.) water cooled, 1100 degrees Fahr. (30 min.) cooled in air.

patches are almost obscured by the lighter of the pearlite areas); presumably with this amount of manganese the eutectoid point lies somewhere between 0.55 and 0.60 per cent carbon. Particular attention is invited to the fact that this steel is *not* brittle. Its properties in the annealed state are good although it is perhaps somewhat harder than might be desired for free machining. The heat-treated alloy shows an excellent combination of properties—high proportional limit, good ductility and the "star" fracture so common to the stronger types of alloy steels, particularly the nickel-chromium combinations.

Ingot 443 (Fig. 6) lies in Guillet's upper transition zone. In photographs (a), (b), (d), (f) and (h) the dark masses are troostite and the groundmass a mixture of austenite and martensite. For these low-magnification photographs which were used to illustrate the general conformation of the structural components, it was not always possible to etch in such manner as to define both austenite and martensite without destroying the outlines of the troostite and at the same time merging the latter with the martensite. Fig. 6 (b) approaches closest to the desirable condition of etching; here the three constituents are clearly visible, while in (c), (e) and (g), austenite and martensite only are present. These specimens are all quite soft because of the presence of the austenite, but the poor tensile test results are readily anticipated from the hard constituents in the microstructure.

The alloy containing 0.50 per cent carbon and 14.0 per cent manganese is entirely austenitic; its structure is in no wise changed by simple heat treatments. The tensile properties are good, although the proportional limit is very low and the elongation much less than would be expected from a consideration of the proportional limit along with hardness and constitution.

Coming to a consideration of the higher carbon steels, ingot 449 shows no structural indications not found in simple carbon steels, with the possible exception that a eutectoid steel is obtained in the presence of this amount of manganese, with a somewhat lower carbon percentage than is indicated by a study of the plain carbon steels. The quenched specimens naturally show coarse-grained martensite due to the high quenching temperature employed. Again it should be noted that this metal is not brittle, particularly after heat treatment. The quenched and drawn bar reported in

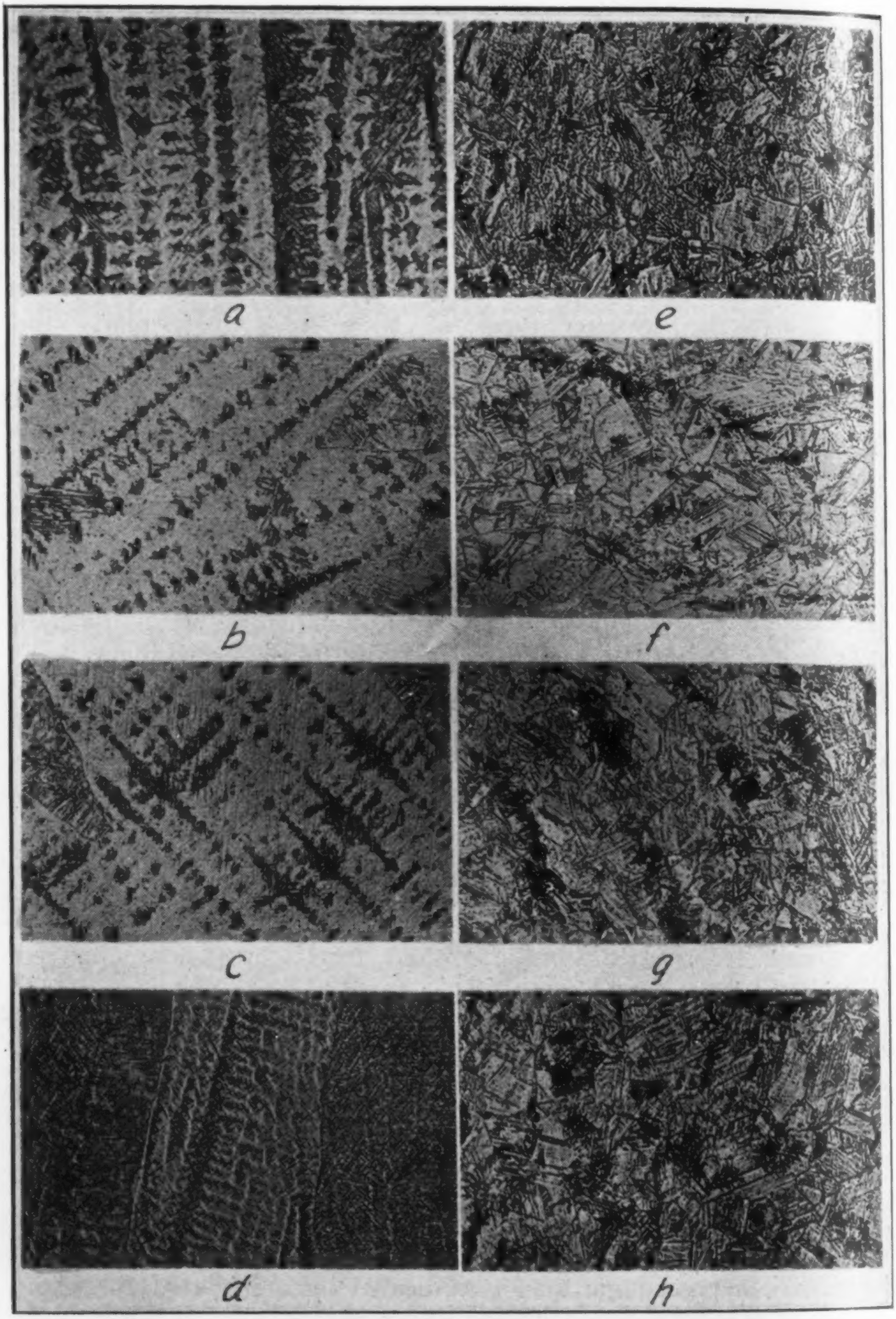

Fig. 4—Carbon, 0.05 per cent; manganese, 16.35 per cent. All magnifications x 100. (a), (b), (c), (d) cast; (e), (f), (g), (h) forged. (a) as cast; (e) as forged; (b) and (f) 1700 degrees Fahr. (15 min.) furnace cooled; (c) and (g) 1750 degrees Fahr. (15 min.) water quenched; (d) and (h) 1750 degrees Fahr. (15 min.) water cooled, 1100 degrees Fahr. (30 min.) cooled in air.

Table VII, when compared with carbon steel of eutectoid composition, shows for equal strength and ductility a proportional limit approximately 25 per cent higher.

The 0.78 per cent carbon steel containing 4.40 per cent manganese consists of martensite and austenite as cast, but troostite and austenite upon cooling in air after forging. On annealing, the structure is a mixture of pearlite and sorbite containing small areas of ferrite; these may be due to negative segregation of carbon in the branches of the dendrites which is not completely removed by forging. Quenching develops a rather homogeneous mixture of austenite and martensite which when drawn reverts to a condition closely resembling that of the annealed state but containing in place of pearlite some troostite not distinguishable in the photographs. Tensile properties are such that this steel would serve no useful purpose—at least from a structural viewpoint.

Ingot 446 (Fig. 10) is austenitic as cast; incidentally, in this photomicrograph, the primary dendritic structure and its independence of the secondary crystal boundaries is very pronounced. The forged specimen consists of patches of austenite and nodules of troostite in a martensitic ground mass. Annealing produces a coarse structure of troostite in a matrix of austenite and martensite. On quenching, the alloy becomes 100 per cent austenitic, the grain size being unusually small, while after reheating at 1100 degrees Fahr., troostite again is formed although more finely divided and in greater amount than after annealing; the cause for this is to be sought not only in the temperature but also the rate of cooling in each operation. The physical tests reflect the hardness of the troostite-martensite-austenite mixture and show also that the fine-grained austenite of this low manganese content has, in comparison with other austenitic steels about to be described, a lower strength and ductility.

With over 12.0 per cent manganese and 0.94 per cent carbon, a steel is produced that as cast is entirely austenitic, (Fig. 11); as forged, however, there are in addition to austenite, patches of troostite and dark etching narrow grain boundaries. In the annealed state the matrix is still austenite, containing patches of troostite but the grain boundaries are not entirely troostitic, there being portions which react toward etching reagents exactly as does the cementite of carbon steels. Quenching yields a completely austenitic material, which in the forged condition reproduces

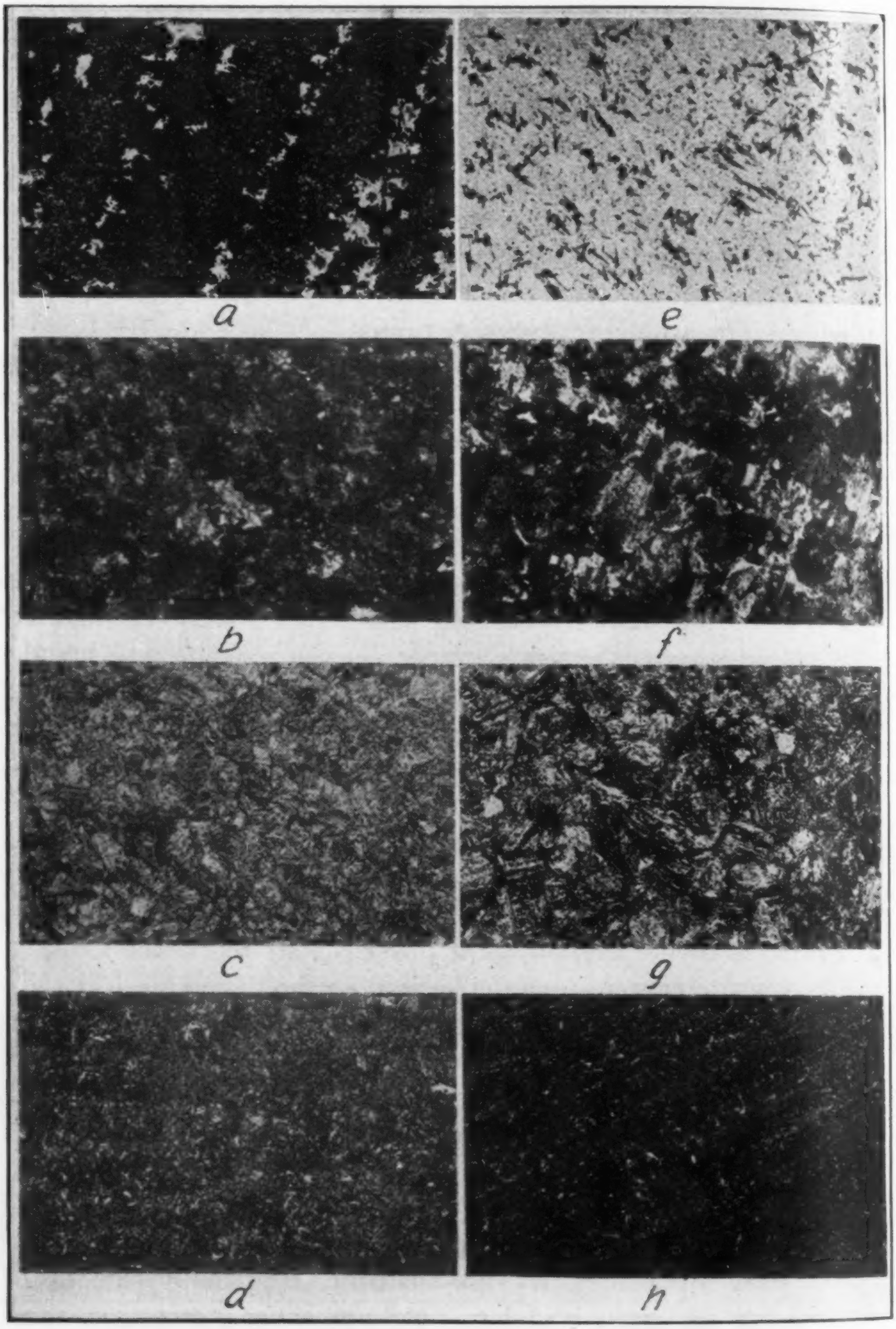

Fig. 5—Carbon, 0.45 per cent; manganese, 3.58 per cent. All magnifications x 100. (a), (b), (c), (d) cast; (e), (f), (g), (h) forged. (a) as cast; (e) as forged; (b) and (f) 1600 degrees Fahr. (15 min.) furnace cooled; (c) and (g) 1650 degrees Fahr. (15 min.) water quenched; (d) and (h) 1650 degrees Fahr. (15 min.) water cooled, 1100 degrees Fahr. (30 min.) cooled in air.

quite well the physical values reported by Hadfield[13] and by Potter.[14] The slightly lower values for the author's steel may undoubtedly be ascribed to the very low cross-sectional reduction in forging which amounted to about 10 to 1; this is considerably lower than for similar commercial steels. Drawing the quenched specimens causes the return of some troostite.

Fig. 12, contains the microstructure of ingot 445, analyzing 1.20 per cent carbon and 4.62 per cent manganese. As cast, the major portion of the steel is composed of austenite and troostite; fine cementite grain boundaries also are present. A prominent feature, however, is the numerous dark-etching needles to which Guillet applied the name "troosto-sorbite" but which most of the recent writers on this subject have termed "carbides." Annealing gives a structure similar to that found in carbon steels cooled somewhat less slowly from the annealing temperature—cementite boundaries in a matrix of sorbite and some pearlite. After quenching, the steel is almost completely austenitic; there are a few patches of a dark etching constituent, which in the cast metal, at this magnification, are not so readily distinguishable from the closely packed twins of the austenite. Drawing causes a reversion to the sorbitic state, with needles and globules of free cementite; the details of this structure are given in Fig. 17 (a).

With manganese increased to over 8.0 per cent the conditions recorded in Fig. 13 occur. As cast there is found austenite containing cementite, troostite and the "carbide" or "troosto-sorbite" needles and after forging austenite with dark-etching grain boundaries containing an occasional patch of troostite. On annealing troostite and cementite are present in the austenite; quenching of the cast metal from 1650 degrees Fahr. shows them incompletely dissolved in the austenite, although after treating the forged sample in the same manner, they are absent. Strangely enough, this apparently homogeneous austenite does not possess very good tensile properties; also the hardness test does not show any difference between the cast and forged quenched samples. Drawing to 1100 degrees Fahr. produces a rapid increase in hardness and a structure that consists of cementite, troostite and "carbide" needles in a small amount of residual austenite; the details are visible in Fig. 17 (e).

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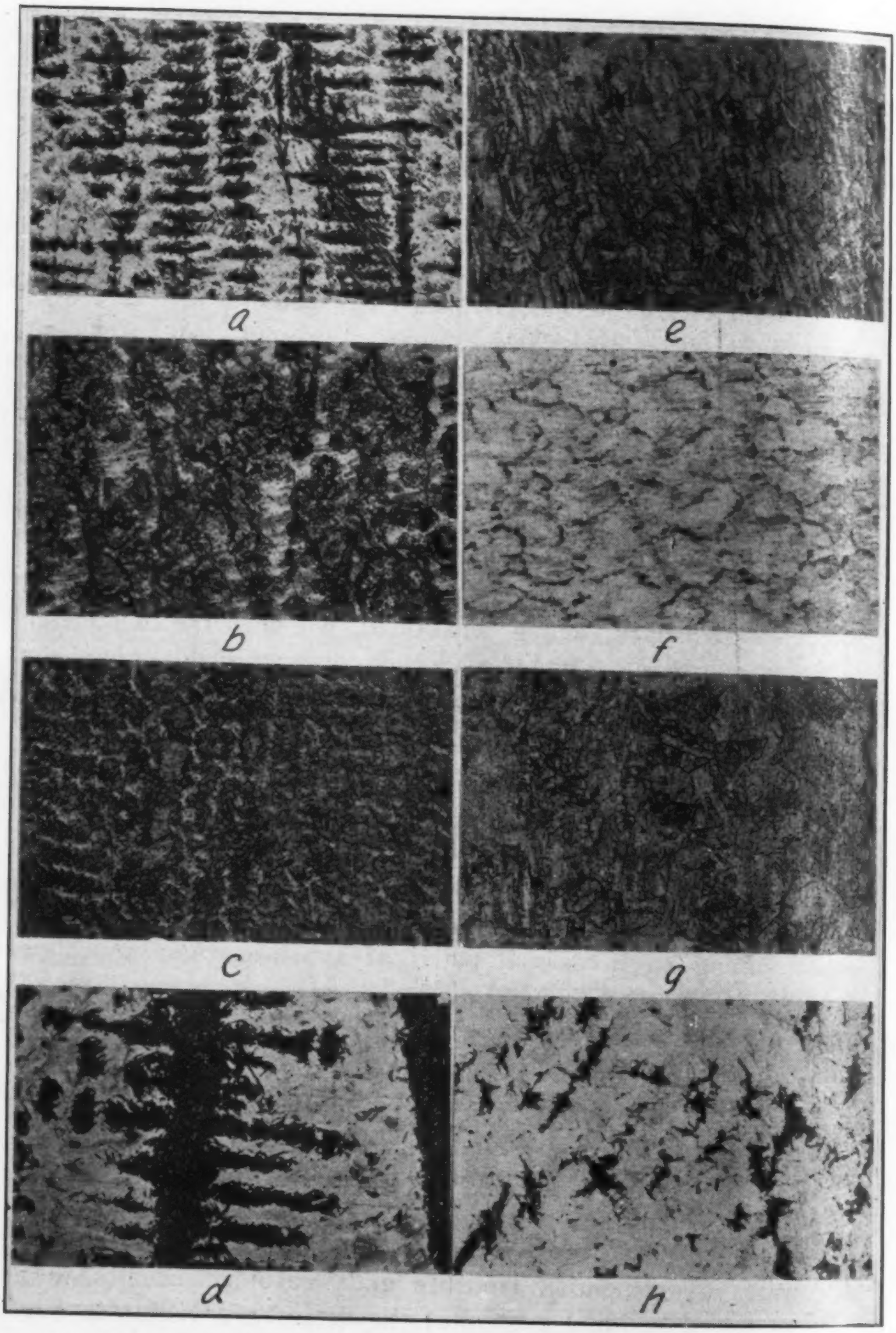

Fig. 6—Carbon, 0.48 per cent; manganese, 8.72 per cent. All magnifications x 100. (a), (b), (c), (d) cast; (e), (f), (g), (h) forged. (a) as cast; (e) as forged; (b) and (f) 1600 degrees Fahr. (15 min.) furnace cooled; (c) and (g) 1650 degrees Fahr. (15 min.) water quenched; (d) and (h) 1650 degrees (15 min.) water cooled, 1100 degrees Fahr. (30 min.) cooled in air.

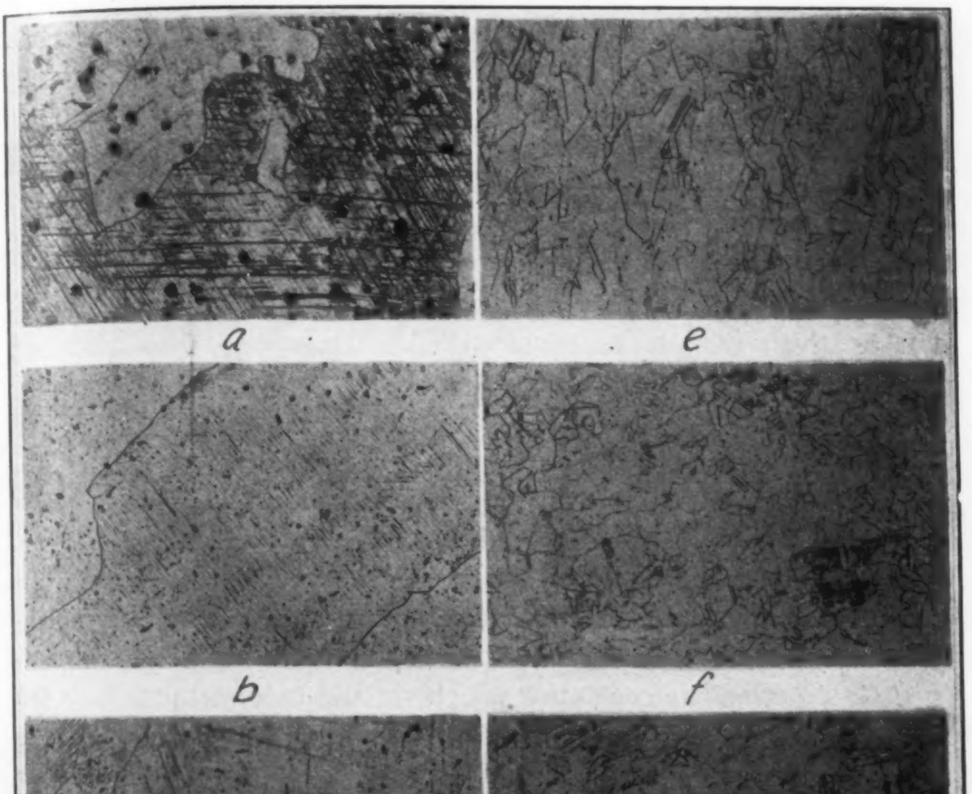

Fig. 7—Carbon, 0.46 per cent; manganese, 14.39 per cent. All magnifications x 100. (a), (b), (c), (d) cast; (e), (f), (g), (h) forged. (a) as cast; (e) as forged; (b) and (f) 1600 degrees Fahr. (15 min.) furnace cooled; (c) and (g) 1650 degrees Fahr. (15 min.) water quenched; (d) and (h) 1650 degrees Fahr. (15 min.) water cooled, 1100 degrees Fahr. (30 min.) cooled in air.

When cast or forged, the structure of the 1.25 per cent carbon steel with 12.0 per cent manganese (Fig. 14) is not materially different from the 8.0 per cent alloy. After annealing the metal is still quite similar; the troostite particles are, however, noticeably smaller and the "carbide" needles are quite prominent in both the cast and forged condition. Quenching the cast metal produces a structure very similar to that found with 8.0 per cent manganese, but in the forged specimen leaves appreciable amounts of the dark-etching grain-boundaries unabsorbed. Drawing the quenched samples brings about the structure characteristic of the annealed state.

One alloy was made to study the effect of very high carbon and moderate manganese content but unfortunately the former was higher than desired. In all conditions except the quenched state, the photographs of Fig. 15 show structures of cementite, sorbite and pearlite similar to those of high carbon steels with lower manganese. Quenching produces a fine-grained austenite with intercrystalline masses of cementite which, in the cast metal follow the branches of the dendrites and in the forged alloy are banded in the direction of working. An effort was made to put this cementite into solution by air-cooling from 1980 degrees Fahr. but, as indicated by the tests (and metallographic confirmation) this was not accomplished. Complete solution of cementite for this steel can be had probably only above the liquidus temperature; the properties of very high carbon-low manganese austenite must be studied with a slightly lower carbon content.

Theoretical explanations of the metallography of manganese steels have not been entirely conclusive, particularly those applied to steels of the higher manganese proportions. Although there may be disagreement in the quantitative details, it is generally conceded that for steels under 3.0 per cent manganese, increase in the proportion of manganese causes a lowering of the various thermal critical points and a movement of the loci of these points as represented on the iron-carbon diagram, slightly to the left, thus giving a eutectoid point at a carbon content increasingly lower. Directly related to these facts is the sluggishness, in response to heat treatment, created by additions of manganese.

In general, operation of these same influences is manifested with higher proportions of the element, as translated by Guillet's equilibrium diagram, (Fig. I). This diagram is similar to that for

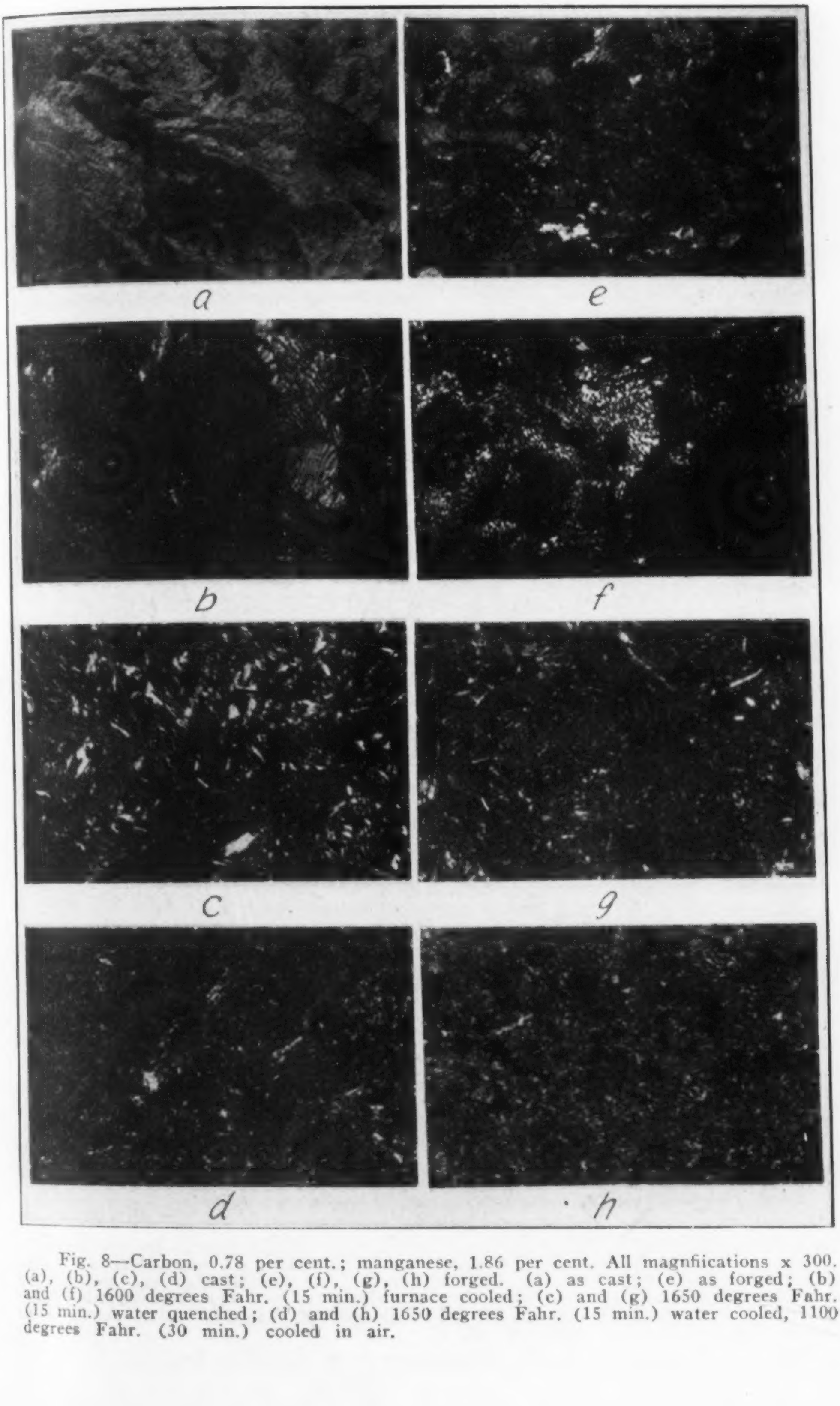

Fig. 8—Carbon, 0.78 per cent.; manganese, 1.86 per cent. All magnfiications x 300. (a), (b), (c), (d) cast; (e), (f), (g), (h) forged. (a) as cast; (e) as forged; (b) and (f) 1600 degrees Fahr. (15 min.) furnace cooled; (c) and (g) 1650 degrees Fahr. (15 min.) water quenched; (d) and (h) 1650 degrees Fahr. (15 min.) water cooled, 1100 degrees Fahr. (30 min.) cooled in air.

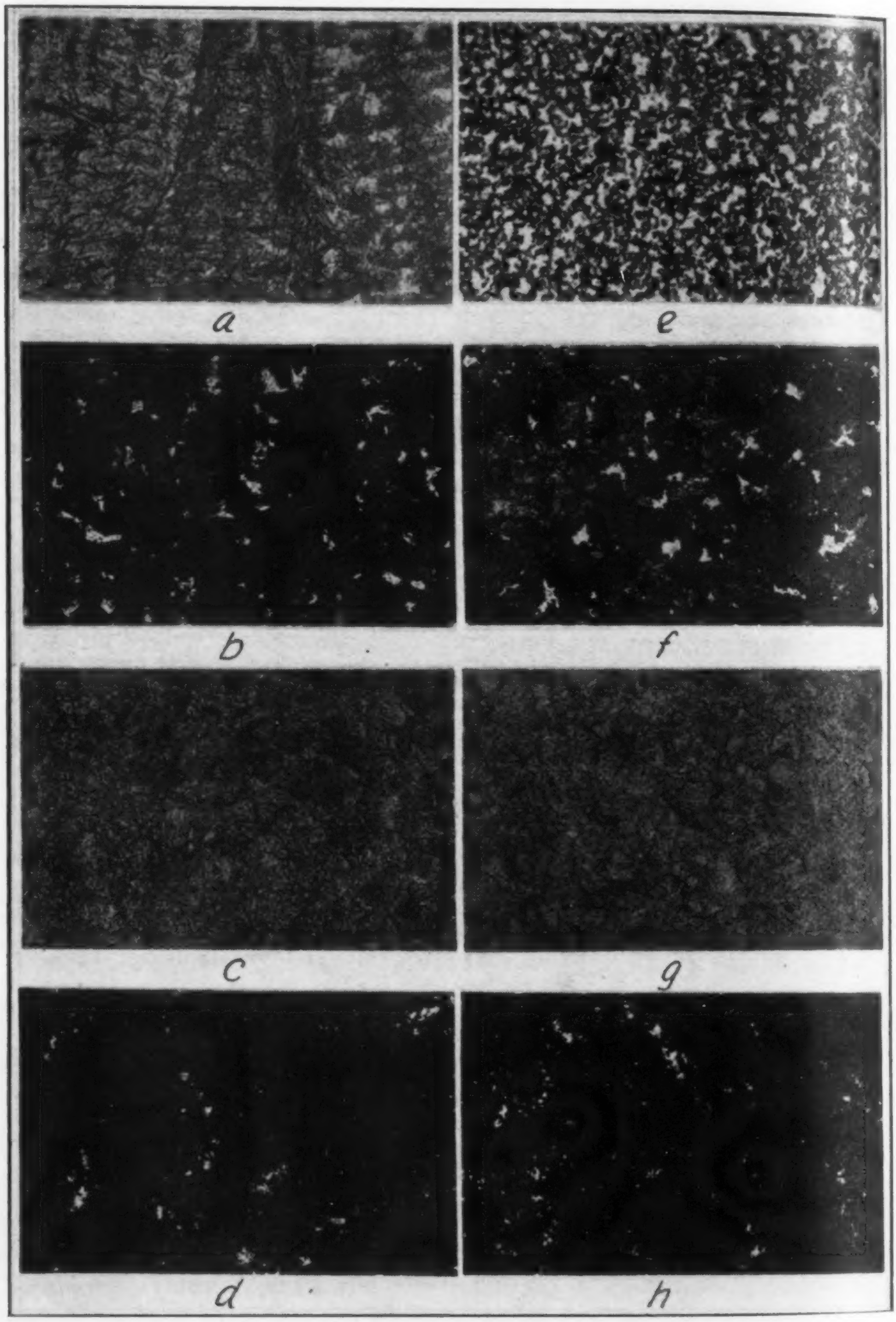

Fig. 9—Carbon, 0.78 per cent; manganese, 4.40 per cent. All magnifications x 100. (a), (b), (c), (d) cast; (e), (f), (g), (h) forged. (a) as cast; (e) as forged; (b) and (f) 1600 degrees Fahr. (15 min.) furnace cooled; (c) and (g) 1650 degrees Fahr. (15 min.) water quenched; (d) and (h) 1650 degrees Fahr. (15 min.) water cooled, 1100 degrees Fahr. (30 min.) cooled in air.

nickel steels with the exception that the two areas showing troostite are, in the case of the nickel steels, entirely absent, leaving the entire triangle a martensitic area. In this way Guillet has recorded results which show those differences between the two groups of steels created by the fact that manganese is a carbide-forming element, whereas nickel is not. However, the microstructure of steels high in manganese (and carbon) is not entirely accounted for in this way. Particularly do steels of the austenitic area containing carbon in excess of 1.0 per cent, show structures not accounted for by this diagram. The different stages of decomposition of the austenite of steels of varying carbon and manganese contents, created by both thermal and mechanical causes have received some study but hardly sufficient to furnish a comprehensive theory of their behavior. Such an explanation must account for the presence of the cementite network, the dark-etching hard network, the needles of "carbide" or "troosto-sorbite" and the possibility of martensitic formations. The hardening of "manganese steel" by cold work has been explained by the formation of martensite or cementite precipitated on slip planes; if martensite occurs from this cause, it would seem reasonable to infer that it would also be the first constituent to form in the thermal transformation of the austenite, but this is not by any means certain. Occurrence of the dark etching needles is most common in the steels of higher carbon content, and when it is considered that for a given percentage of manganese, increase of carbon removes the resultant metal more and more from the martensitic and troostitic areas of Fig. I, it does not seem reasonable that all of these acicular particles are of a constituent intermediate between austenite and pearlite. However, if such should be their nature, then in "Hadfield's manganese steel," the thermal transformations are not so much lowered as they are suppressed and data on their location would be of interest. On the other hand, if these needles are carbides, then there must be more than one manganese-iron-carbon compound or mixture of compounds to be accounted for and a comprehensive theory must explain their occurrence and properties. These are but a few of the points necessary to a thorough understanding of these alloys for their magnetic behavior introduces additional complications.

Possibilities of Manganese Steels

It is most difficult in a necessarily restricted space to cover in

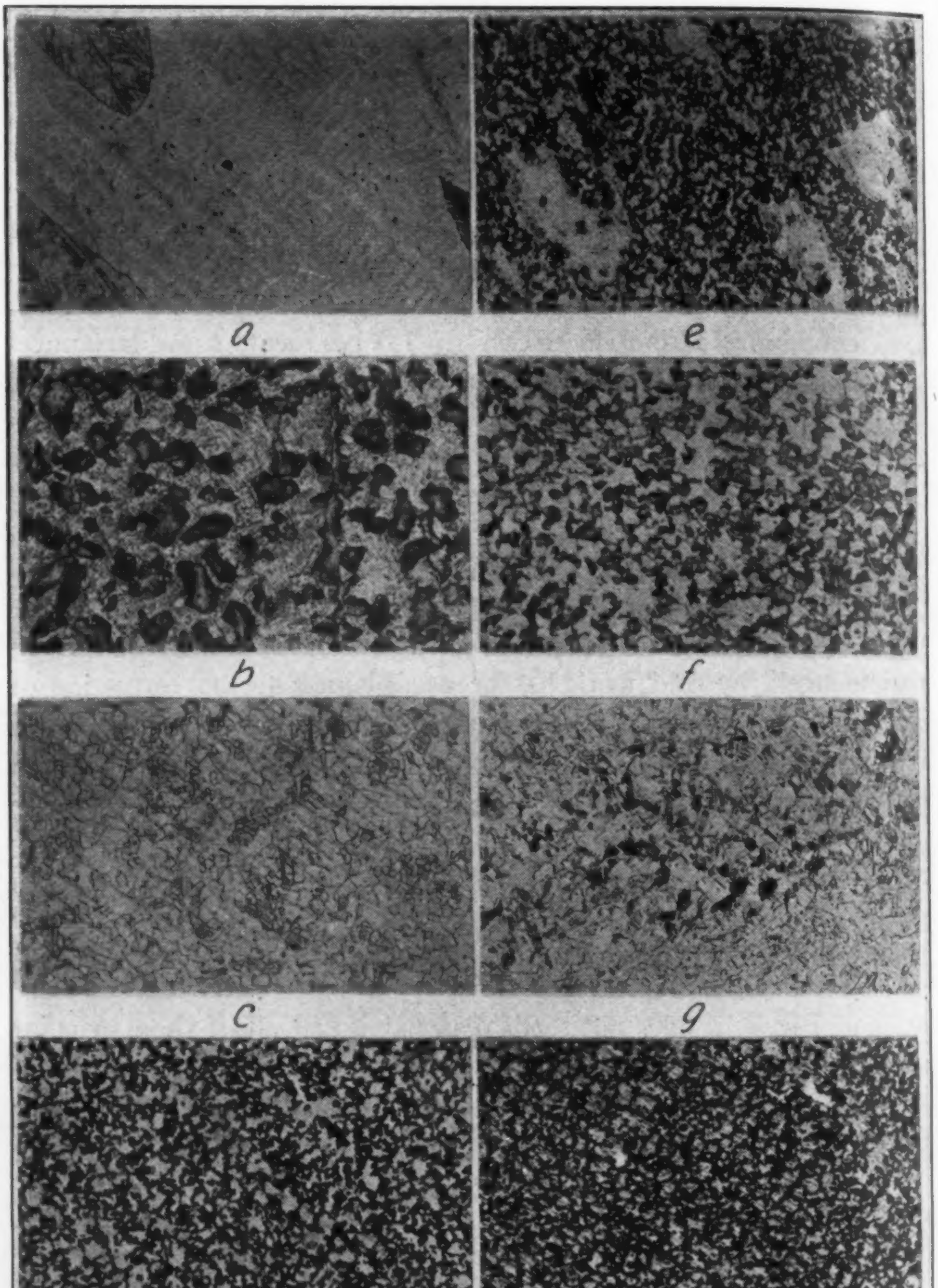

Fig. 10—Carbon, 0.81 per cent; manganese, 8.87 per cent. All magnifications x 100. (a), (b), (c), (d) cast; (e), (f), (g), (h) forged. (a) as cast; (e) as forged; (b) and (f) 1600 degrees Fahr. (15 min.) furnace cooled; (c) and (g) 1650 degrees Fahr. (15 min.) water quenched; (d) and (h) 1650 degrees Fahr. (15 min.) water cooled, 1100 degrees Fahr. (30 min.) cooled in air.

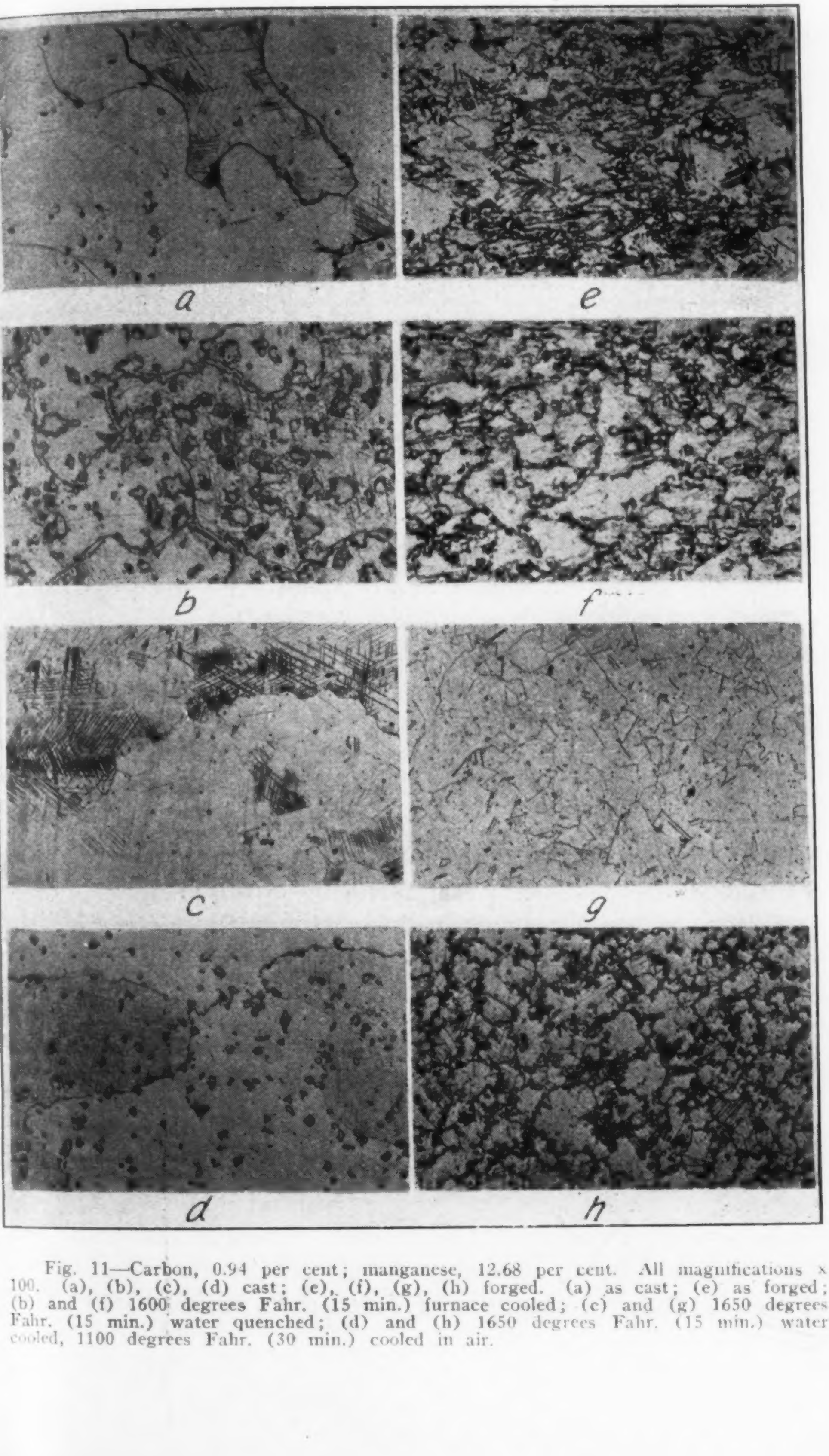

Fig. 11—Carbon, 0.94 per cent; manganese, 12.68 per cent. All magnifications × 100. (a), (b), (c), (d) cast; (e), (f), (g), (h) forged. (a) as cast; (e) as forged; (b) and (f) 1600 degrees Fahr. (15 min.) furnace cooled; (c) and (g) 1650 degrees Fahr. (15 min.) water quenched; (d) and (h) 1650 degrees Fahr. (15 min.) water cooled, 1100 degrees Fahr. (30 min.) cooled in air.

detail the entire field of the application of manganese in varying the physical characteristics of steels. Some of the directions for further development and application have, however, been indicated and may well bear repetition or emphasis along with possible uses in more complex systems.

In steels under 0.40 per cent carbon there have been many applications of manganese contents up to about 1.5 per cent. There have also been a few uses of low-manganese steels of similar manganese content but with higher carbon proportions. All of these uses seem fewer than are justified by the circumstances. Here is available a cheap addition agent capable of replacing to advantage certain other alloy additions or, viewed in another light, of providing at small cost an increase in ductility (and related characteristics) by using it in combination with a lowering of the carbon. In some cases, it is even doubtful whether such increase in cost would occur when the decrease in manufacturing losses created by the change in carbon content, is considered. Due perhaps to the widespread association of brittleness with the combination of high carbon and high manganese, specifications for carburizing steels have limited the presence of the latter element to 0.60 per cent or less. It is most probable that research in the direction of low-carbon steels with up to 2.0 per cent manganese, may show the above limit to be most arbitrary and may further indicate combinations that for some purposes could replace other alloy steels now in use. The characteristics of quaternary combinations including 1.0 to 2.0 per cent manganese require further investigation and the study of such steels containing vanadium, molybdenum, chromium, copper, etc., may develop structural materials of much value. In this connection the use by the Naval Gun Factory of a casting and forging steel containing 0.30 per cent carbon, 1.0 per cent manganese, 1.5 per cent nickel and 0.4 per cent copper, is of interest.

The high-manganese steels also seem deserving of additional research. The study of the relations between chemical composition, melting and casting practice, mechanical treatment and thermal treatment, as combining to produce the characteristics of the ultimate product have not yet brought perfection. Troostite, cementitic and also "carbide" masses, network and needles have often been causes of failure; the microstructure of failed parts varies widely as to

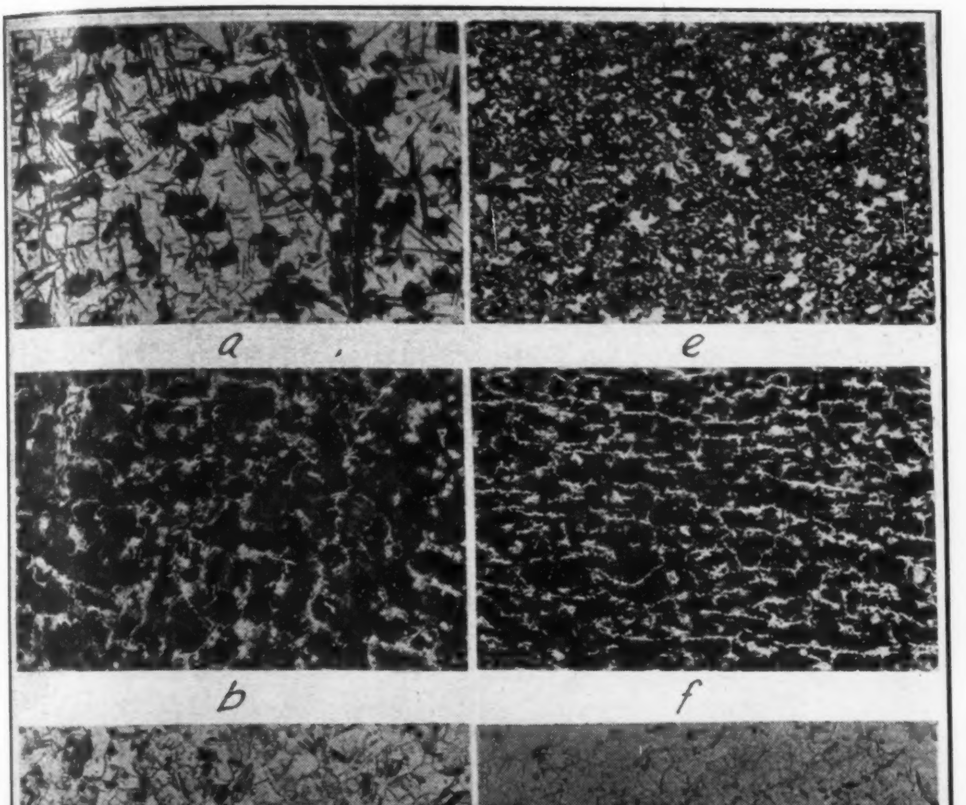

Fig. 12—Carbon, 1.20 per cent; manganese, 4.62 per cent. All magnifications x 100. (a), (b), (c), (d) cast; (e), (f), (g), (h) forged. (a) as cast; (e) as forged; (b) and (f) 1600 degrees Fahr. (15 min.) furnace cooled; (c) and (g) 1650 degrees Fahr. (15 min.) water quenched; (d) and (h) 1650 degrees Fahr. (15 min.) water cooled, 1100 degrees Fahr. (30 min.) cooled in air.

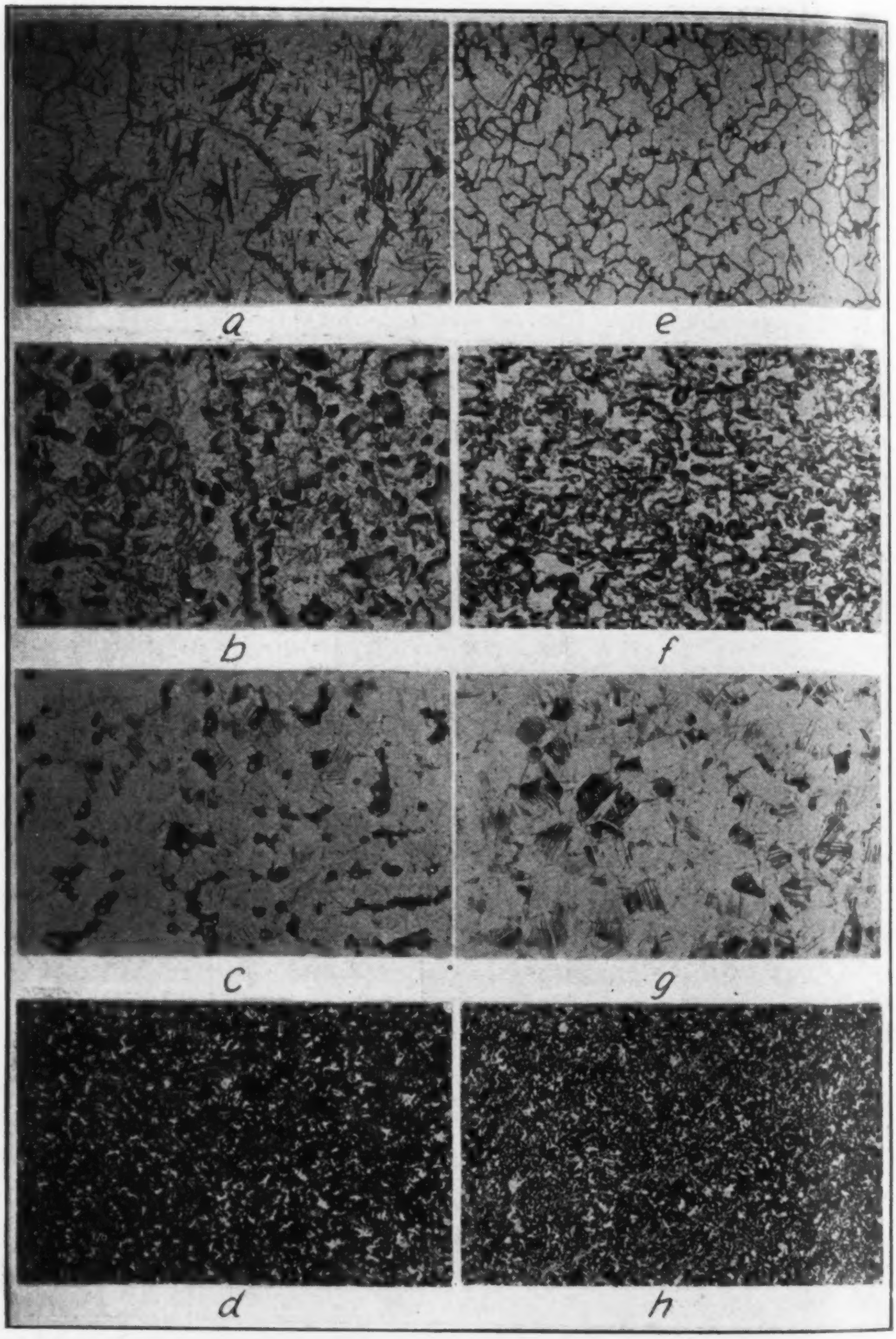

Fig. 13—Carbon, 1.27 per cent; manganese, 8.68 per cent. All magnifications x 100. (a), (b), (c), (d) cast; (e), (f), (g), (h) forged. (a) as cast; (e) as forged; (b) and (f) 1600 degrees Fahr. (15 min.) furnace cooled; (c) and (g) 1650 degrees Fahr. (15 min.) water quenched; (d) and (h) 1650 degrees Fahr. (15 min.) water cooled, 1100 degrees Fahr. (30 min.) cooled in air.

the presence or absence of the above constituents; the cause or causes of the occurrence of each has not received sufficient attention. Naturally any modification that will help to curtail the number of failures by removing the causes, without simultaneously reducing those properties upon which serviceability depends, will be a step forward. The nature of the hard constituents usually responsible for failures and their mode of occurrence cannot be entirely explained from these few tests but certain facts stand forth prominently and help point a way. The alloys coming within the scope of the term "Hadfield's manganese steels" are covered in Figs. 10, 11, 13 and 14. It will be observed that the needles of "carbide" occur only in the higher carbon steels, that the production of a 100 per cent austenitic structure (hard constituents absent) is readily accomplished at a low temperature in the low-carbon steels, but not so readily in the higher carbon steels; also for a given manganese content, decomposition of the austenite into hard constituents on reheating, is greater in amount in the steels with higher carbon. This difficulty of complete solution of the "carbides" at low quenching temperature is clearly brought out in Fig. 16; as in the previous instances the formation of 100 per cent austenite is more difficult in the cast state. Fig. 16(g) is a clear exposition of the situation; this photograph shows at low magnification the edge of the bar illustrated in 16(e); analysis of a cross-section of the bar, excluding the surface, gave a value of 1.25 per cent carbon, but at the edge there was found only 0.96 per cent. Of course, austenitic structures can be obtained if the quenching temperature is sufficiently high but such increase, aside from the added cost of fuel and furnace upkeep, produces an enlarged grain (Fig. 17) and greater quenching stresses that ultimately mean inferior mechanical properties (Table V). These considerations naturally apply to castings more forcefully than to rolled or forged bars; they are also more applicable to thick than to thin sections. Because of such conditions the author favors the use of a slightly lower carbon content than is the custom of many producers. In some cases this can be accomplished with existing materials and processes; in others it must await the development of low-priced manganese alloys containing less carbon than those now manufactured. The effect of such a change of composition on

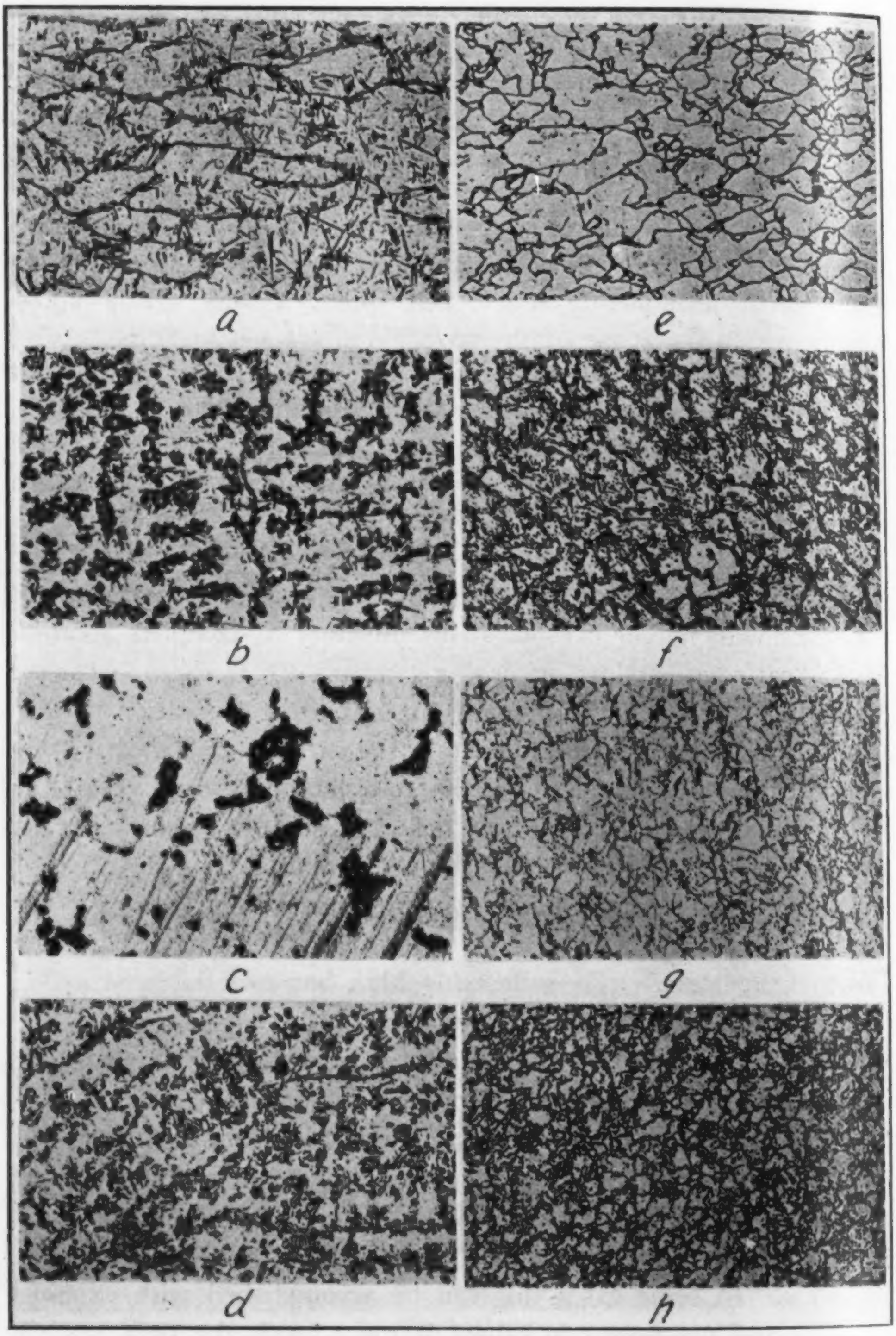

Fig. 14—Carbon, 1.22 per cent; manganese, 12.40 per cent. All magnifications x 100. (a), (b), (c), (d) cast; (e), (f), (g), (h) forged. (a) as cast; (e) as forged; (b) and (f) 1600 degrees Fahr. (15 min.) furnace cooled; (c) and (g) 1650 degrees Fahr. (15 min.) water quenched; (d) and (h) 1650 degrees Fahr. (15 min.) water cooled, 1100 degrees Fahr. (30 min.) cooled in air.

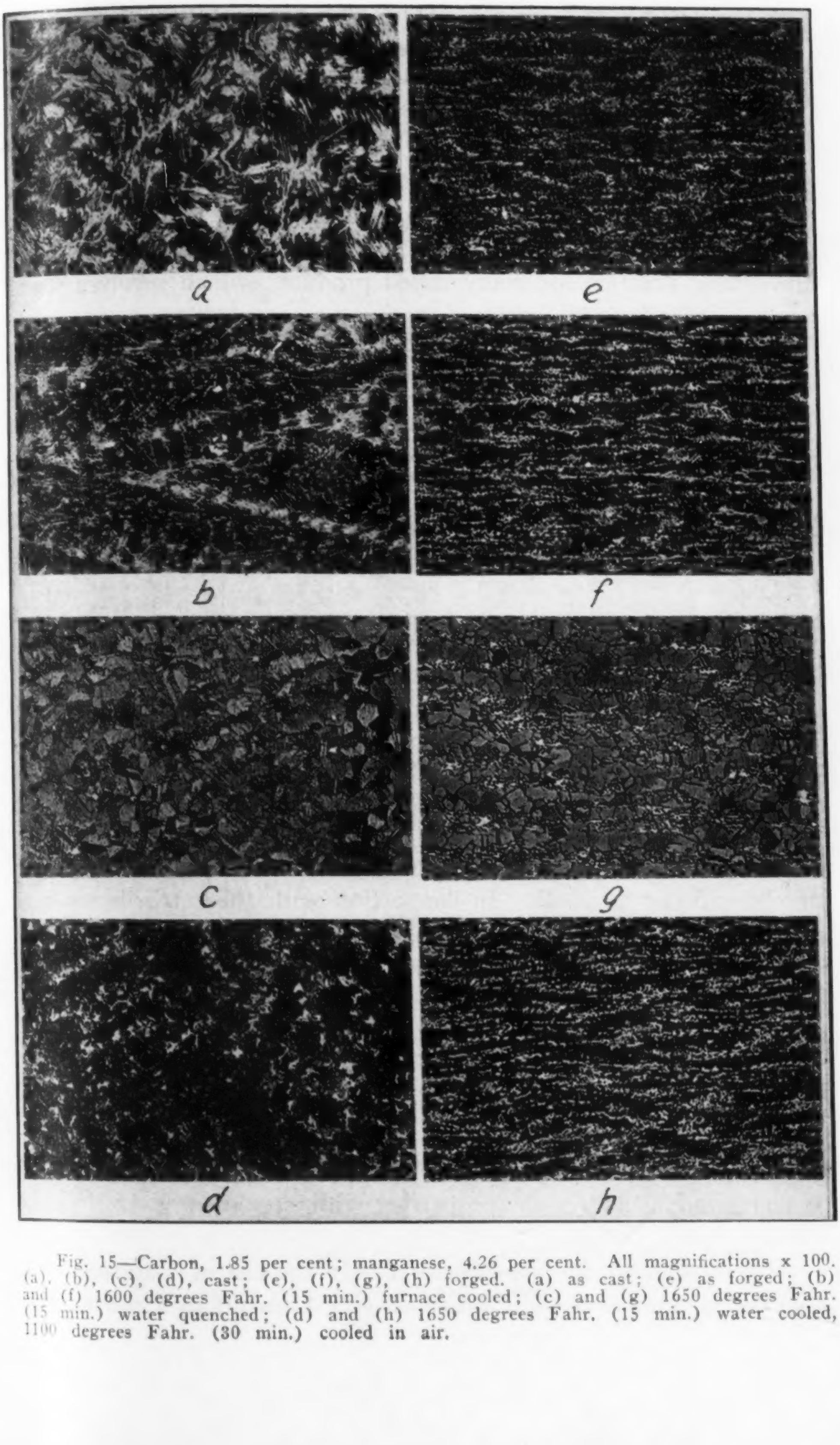

Fig. 15—Carbon, 1.85 per cent; manganese, 4.26 per cent. All magnifications x 100. (a), (b), (c), (d), cast; (e), (f), (g), (h) forged. (a) as cast; (e) as forged; (b) and (f) 1600 degrees Fahr. (15 min.) furnace cooled; (c) and (g) 1650 degrees Fahr. (15 min.) water quenched; (d) and (h) 1650 degrees Fahr. (15 min.) water cooled, 1100 degrees Fahr. (30 min.) cooled in air.

the tensile properties is slight and probably in favor of the lower carbon combination. Using for each steel the minimum quenching temperature required to obtain complete austenitization, it is doubtful whether any appreciable difference in proportional limit would result, whereas it is reasonably certain that there would be a gain in impact resistance with the finer grain resulting from the lower quenching temperature. In favor of this lower quenching temperature made possible by the decrease in carbon is the present quenching practice for many rolled products, which involves water

Table IX

Tensile Properties of Manganese Steel

Carbon Content—1.25 per cent
Manganese Content—7.62 per cent

Bar No.	Condition	Heat Treatment	Prop. Limit lbs. sq. in.	Tensile Strength lbs. sq. in.	Elongation in 2" per cent	Reduction of Area per cent	Fracture	Brinell
X-103	Cast	1650°F Water	55000	85500	3.8	5.9	Ang. Gran.	251
X-102	Cast	1800°F Water	49900	75800	7.3	11.3	Ang. Gran.	192
X-101	Cast	2000°F Water	46800	77400	16.0	22.2	Ang. Gran.	...
X-107	Forged	1650°F Water	55000	105400	11.3	13.9	*Sq. Gran.	217
X-106	Forged	1800°F Water	46800	102800	25.5	29.1	*Sq. Gran.	187
X-105	Forged	2000°F Water	45800	100300	25.8	31.1	*Sq. Gran.	...

* Broke in points.

cooling immediately following rolling and without reheating. Here slight delays mean "carbide" precipitation and a resultant product not in its best possible condition for impact resistance. Referring to Table VII, a higher quenching temperature to avoid the hard constituents in test bar X-33 would have slightly lowered the proportional limit and increased the elongation, but the resultant bar would still be inferior to X-21. In connection with these tensile tests it must be remembered that better results than X-33 or its modification by a higher quenching temperature as indicated, are obtainable in practice because the present test bars were made by a 10 to 1 reduction from the ingot whereas usual practice for rails is about 40 to 1 and for bars often 300 to 1 or more. The figures of Table IX support the statements relative to the effect of complete solution of hard constituents and also the effect of working; the forged bars were produced by a reduction of 60 to 1 and should be compared as to tensile properties with specimen X-15 (Table VII).

There remains for consideration only the use of manganese in large percentages along with other alloying elements as a constituent

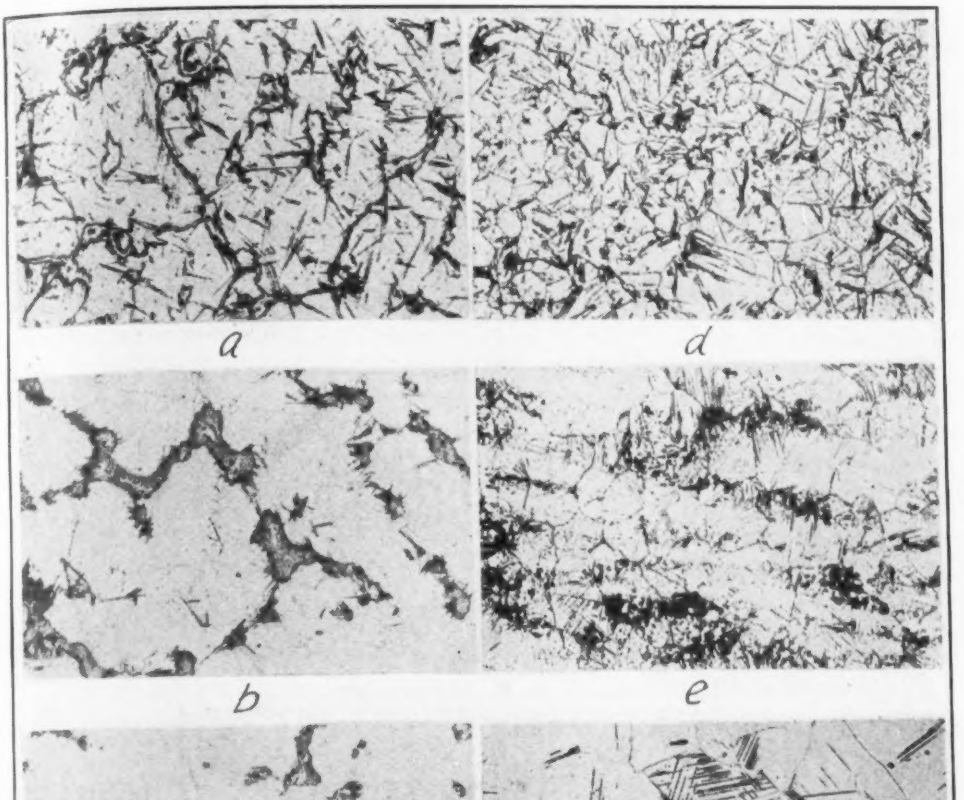

Fig. 16—Carbon, 1.25 per cent; manganese, 7.62 per cent. Magnifications (except g) x 100. (a), (b), (c), cast; (d), (e), (f), (g) forged. (a) as cast; (d) as forged; (b) and (e) 1650 degrees Fahr. (15 min.) water quenched; (c) and (f) 1800 degrees Fahr. (15 min.) water quenched; (g) same as (e) showing surface of bar, magnification x 40.

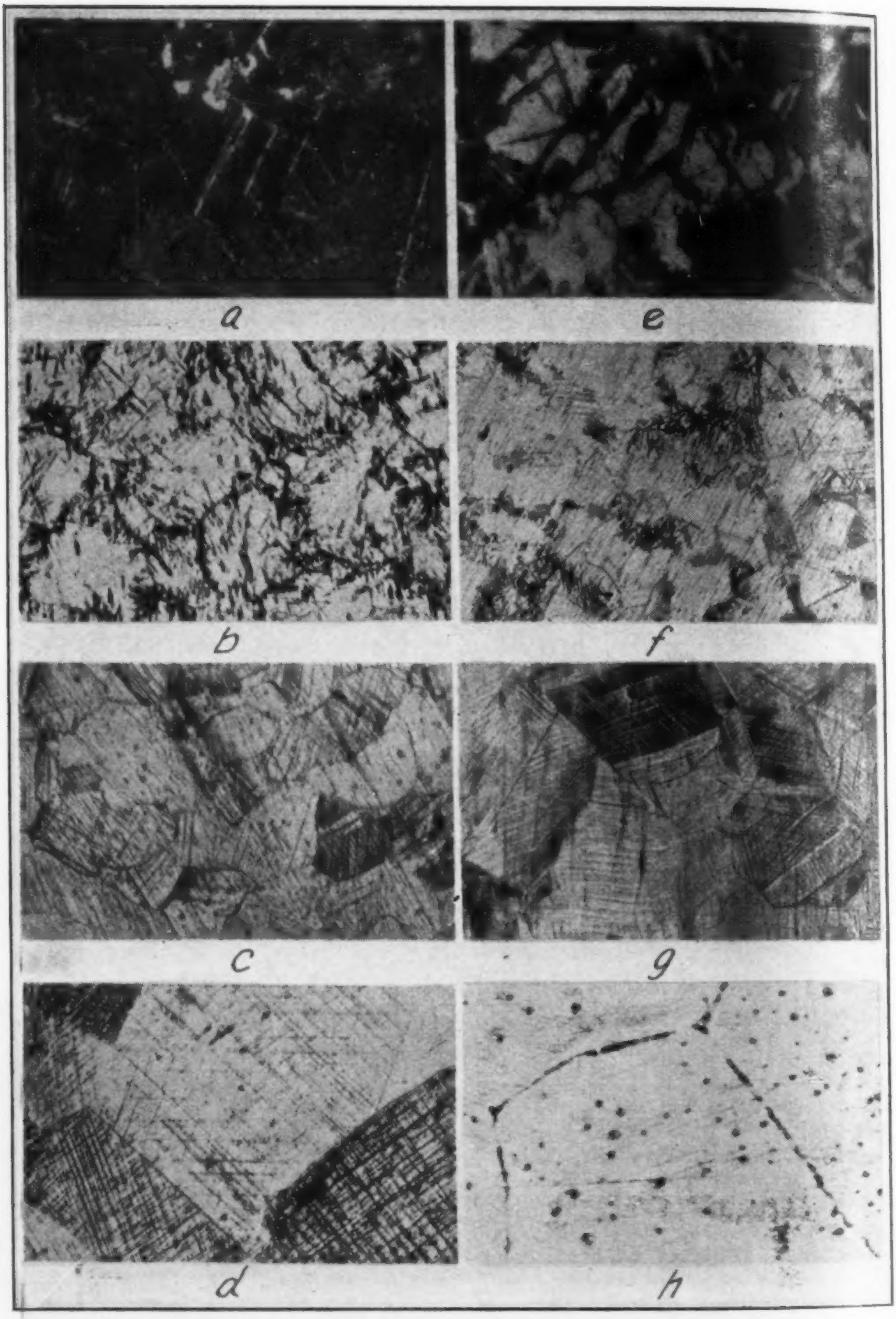

Fig. 17—(a), same as 12 (d) x 800; (e), same as 13 (d) x 800. (b), (c), (d) (f), (g), (h), rail steel, carbon, 1.10 per cent; manganese, 11.42 per cent; (b) 1290 degrees Fahr. water quenched; (f) 1560 degrees Fahr. water quenched; (c) 1650 degrees Fahr. water quenched; (g) 1920 degrees Fahr. water quenched; (d) 2190 degrees Fahr. water quenched; (h) 2370 degrees Fahr. water quenched.

of austenitic steels. Improvement of the wear-resisting Hadfield steels has been attempted and in this direction the introduction of chromium has been successful in raising the proportional limit although at the expense of considerable ductility. However, the use of this combination has not been extensive. Addition of other elements such as nickel, copper and vanadium has been mentioned but no data as to their effects have been made available. The foremost objection to such composition modification appears to be the increased cost, and this objection will not readily be overcome unless extreme improvements are demonstrated.

Within the past few years there has been a rapidly increasing use of austenitic nickel steels containing chromium as a hardening element. They have been advanced as structural steels for applications where resistance to corrosion was a vital factor and have withstood successfully many corrosive influences; in most instances they represent a considerable improvement over the 25.0 and 35.0 per cent nickel steels. During the late war, however, Germany keenly felt her shortage of nickel and undoubtedly because of this, was led to modify these nickel steels by partial substitution of manganese, even though the latter was none too plentiful. The following analyses were made on samples taken from three German submarine periscope tubes acquired during the war period:

No.	C	Mn	Ni	Cr
1	.54	.60	23.67	1.18
2	.73	5.07	16.56	None
3	.71	6.68	11.62	4.17

The first is a nickel steel with a small amount of chromium similar, except for slightly lower manganese and nickel percentages, to an early type of chromium-bearing high-nickel steel produced in this country. Metallographically, the second is approximately equivalent to a 27.0 per cent nickel steel and the third to 25.0 per cent nickel steel with the same chromium content. It is steels similar in composition to the third one in this list that were referred to as having recently been so widely applied, the usual types, however, containing less than 0.50 per cent carbon and as high as 18.0 per cent chromium.

The use, of course, of these austenitic manganese-nickel

steels is not an innovation [15] [16], but is worthy of close attention for although the corrosion-resistance of these steels may be considered low in comparison with austenitic nickel and nickel-chromium alloys, the fact remains that these tubes were functioning well and showed no corrosive effects other than the very thinnest film of oxide. It is always well to heed such occurrences as this, because in the last analysis, it is a combination of cost and ability to meet service requirements that means success or failure.

The author is indebted to Louis Jordan of the United States Bureau of Standards for the preparation of the small ingots and desires also to acknowledge the assistance of Harry Schultz in the metallographic work and J. W. Talley in carrying out the heat treatments.

15. Carpenter, Hadfield and Longmuir—Seventh Report of the Alloys Research Committee, Institution of Mechanical Engineers, 1905.

16. Guillet—Quartenary Steels, *Journal* of the Iron and Steel Institute, 1906.

SOME OBSERVATIONS ON FURNACES AND FUELS INCLUDING THE ELECTRIC FURNACE FOR HEAT TREATING

By E. F. Collins

Abstract

This paper points out the undeniable fact that furnace selection, whether fuel or electric, has been in the past one largely influenced by the promoter rather than the engineer. It is urged that executives avail themselves of the service of the furnace engineer in the future, and it is urged that these engineers make selections after a complete study of the requirements, giving due consideration to the various factors involved and their relative importance. Furnaces should be fitted to processes rather than attempt to fit special processes to standard furnaces.

Attention is briefly called to the adaptability of the electric heat treating furnace of the metallic resistor type for carbon steel heat treatment.

Assuming that proper selection of furnace and fuel has been made, it is urged that intelligent and capable handling and management be added, in order to secure the lowest "over all" costs for the manufactured product.

Finally, if the electric furnace is used, where careful analysis of conditions call for it, substantial "over all" economies are returned.

Industrial Heating a Broad Field

HAVE you ever noted how heat, in one way or another, influences quality, cost, and the utility of practically every manufactured article? Especially is its application far-reaching in the manufacture of metal and its fabrication. Yet it must be confessed that industrial heating in the past has not had the attention of the high-grade engineer, as its importance deserved. All too often the selection of equipment has been left to those who were ruled more strong-

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ly by the promoter, than by the scientific analysis of the requirements. Many essentials such as fuel values, method and efficiency of heat conversion, temperature controls and pyrometers, should receive their full share of technical consideration.

Danger of Wrong Deductions

Many wrong deductions regarding the efficiency of electric heat versus fuel heat, come from comparing an inefficient electric furnace, perhaps improperly operated, and in design not suited to the specific process and manufacturing conditions, with a fuel-fired furnace which is suited to the fuel and the process, and is more efficiently operated. The difference in economy resulting is too often charged to the difference between electric heating and fuel heating. In this connection, the writer recalls an example of such an erroneous deduction. A piece of heating equipment improperly designed for the economical application of electric heat was, nevertheless, fitted with electric heaters. It turned out a product with a consumption of about one kilowatt-hour for 3.5 pounds when electrically heated. This same piece of apparatus was almost ideally suited for fuel heating, and when operated with oil heating, gave a cost for treating the product of only one-ninth of the cost with electricity.

Proper design and proper operation of apparatus for the same work, when electrically heated, gave 35 pounds per kilowatt-hour (or 10 times 3.5). The reason then for doing work at one-ninth the cost in the fuel-fired equipment was that the design was suited to oil heating and unsuited to electric. It would not have been reported that electric heat was nine times more expensive than oil for the same purpose, if those making the comparison had not been mistaken as to the cause of the difference. They erroneously charged it to the use of different "fuels" rather than to wrong designs, which defeated the proper application of electric heat.

Design Should Fit the Fuel and Work

In order to forestall charges of misapplication of a "fuel" designs must take advantage of the inherent characteristics of electricity or a fuel, as the case may be. Again, furnaces of the box type, used by intermittent charging, should not be

compared to "tunnel" type or continuous conveyor type, neither should "noncompensated" or "nonregenerative" furnaces be compared to compensated or regenerative types with the expectation of equal performance. In such cases we should look for a more or less wide variation in performance between the different types when used under the same conditions. The lowest "over all" cost of production will usually demand one particular type furnace, depending upon the requirements of the product.

Relation Between B. t. u. Cost and "Over All" Cost

There is no direct constant relation between the calorific value of a heat source and the "over all" cost, in industrial heating. The "over all" cost is a function of (1) the character of the "heating cycle" required by the product under manufacture, (2) the equipment provided for the application of heat, (3) the conditions under which the equipment is operated, (4) the efficiency of operators, and (5) the cost of the heating medium, be it electricity or fuel. All these factors combined determine the factory costs, using fuel or electricity. The quantity consumed affects the cost of production usually to a lesser degree than any other single factor listed above. Fuel consumption, for a given process, may easily be twice as great in one furnace as in another doing the same work but having a more efficient design. Again, it is true that a well designed equipment may be so inefficiently operated, (especially in fuel furnaces) that it consumes double or treble the quantity of heating fuels or electricity that a watchful and highly efficient operator would use for the same production with correct methods of operation.

Conditions for Minimum Fuel Cost

Few manufacturers can control the price paid for their fuel directly. A manufacturer can, however, just as surely keep his cost of fuel to the minimum, by using furnaces and heating equipment designed to suit his processes and the conditions in his own plant. He should use heating apparatus designed not only to produce heat but which does apply and utilize it with the greatest efficiency in each individual proc-

ess. In other words, he should fit his heating equipment to the process and not attempt to fit his process to the equipment.

Another feature which enters into the selection of a particular fuel or electricity, and which is many times of greater economic value for a heating process than the B.t.u. content of the "fuel" or the perfect release of the heat content; is what has been termed "form value."

Were it not for the "form value," and if the B.t.u. content of the fuel were the whole criterion, then the use of oil or manufactured gas could hardly prove economical in the face of the low cost of bituminous coal, from the standpoint of its B.t.u. content. It must be admitted that this "form value" is somewhat intangible, but in the "over all" cost of production it appears as a very real element.

"Form value" results from physical condition or chemical combinations in a heat energy source, entirely separate and apart from B.t.u. content, such that an advantage comes about in the application of its heat to useful service. Here the price of fuel or electricity, type of furnace, and the heat balance for the process, are excluded from the commonly accepted conception of "form value."

Selecting the Proper Furnace

Hence when the furnace engineer surveys a given process, and considers various fuels or electricity as the source of heat, he should not neglect to give due consideration to "form factor"; a very real factor influencing "over all" costs. This is equally as important and many times more so than such factors as price of fuel or electricity or B.t.u. heat content, heat balance for the process, or the first cost of the heating apparatus.

It is desired to emphasize the absolute necessity for the furnace engineer to make a detailed study and survey covering in detail the foregoing general factors vital to a correct design for heating equipment which will produce the most efficient results. Whether the heating shall be done with fuel or electricity can only be determined from such study. If electricity is selected, then should heat be generated by re-

sistance, by induction, or by the arc? If fuel is to be used, then what form of fuel will give the lowest "over all" cost?

We are accustomed to make careful and exhaustive study of the application of the electric motor in the power field, and of the electric light in the field of illumination, and so must we make the same critical and unbiased study of the best methods of applying electric heat to industrial processes. It is a fact that while the cost of electric heat enters only indirectly into the "over all" cost of production, it enters as a greater factor usually than electric energy does in the motor and lighting fields, therefore, we can afford to use no less exact engineering methods in applying electric heat to industrial heating processes. If fuel heat is to retain its portion of the heating field rightfully belonging to it, then engineers must give the same careful attention to the application of the proper fuel in equipment correctly designed. Much fuel burning equipment is met with today which shows that proper analysis of the application of heat has not been made. Had this been done, many fuel-fired devices that are now in use, would already have been discarded for the electric; while others would have been redesigned to give the most that fuel firing has to offer.

Many Fuel-Fired Furnaces Operate Inefficiently

As illustration of the latter statement, we note in a prominent furnace engineer's bulletin the following illustrations of economy affected by proper selection and design of fuel furnaces to meet heating requirements and plant conditions.

	Increase of Output	
Process	Per Unit Floor Space Per Cent	Unit of Fuel Per Cent
Small drop forge (a)	37	78
Small drop forge (b)	275	27
Small drop forge (c)	250	47
Large drop forge		90
Heat treating steel	17	33
Hardening steel parts	50	
Annealing steel	103	25
Carburizing		90

This list is sufficient to indicate that industrial heating processes should receive the attention of the trained furnace

engineer, and when such practice is followed, is bound to result in much economy. We are apt to be concerned over a matter of one or two per cent in the efficiency of a motor and yet the foregoing table reveals the improvement all the way from 25 to 275 per cent may be secured, not infrequently, by competent furnace engineering. Were we given the opportunity to study conditions existing in the heat treating, hardening, annealing and carbonizing furnaces in this table, giving due consideration to the advantages of the electric furnace, we would, no doubt, conclude that these furnaces would give a still higher "over all" efficiency if electrically heated. This is not mere conjecture, but the result of experience in using the electric heat for these processes. Where quality enters as an important factor, and the usual rates for electric power prevail, it seldom happens that fuel will show lower "over all" cost of manufacture, nor the same great uniformity and high physical characteristics for the heat treated product.

The B. t. u. Cost Factor May Disappear

Exceptional cases exist as illustrated by the hot air pumping engine, in an isolated rural district, and which is very much less efficient than the present day gas engine or oil engine as regards its thermal efficiency or consumption of fuel. Yet it has peculiar advantages such as use of cheap fuel, little need of attention and a resultant "over all" economic value which more than offsets its high consumption of heat B.t.u. for the work done. This is but another illustration of how the quality of B.t.u. consumed and its cost may be completely obliterated by other more important considerations.

We may agree, then, that the B.t.u. value is only one element of the economic value of a fuel for industrial heating when the "over all" cost of manufacture is the controlling consideration, as it should be. Fuel and electric heat each have their fields of usefulness, where one cannot compete with the other; also fields where there is little to commend the use of one as against the other. It would seem that the true furnace engineer should follow the broad law of conservation and urge the use of that type of heat which will conserve our energy supply.

Efficiency of Fuel Burning

Coal, oil, gas and water power are the principal present day sources of energy in the country. This group furnishes energy required by modern conditions. It is estimated that about one-third of this energy is devoted to the production of heat and light, or in other words, something like 150,000,000 tons of coal is used for metallurgical processes. This fuel is used with an average efficiency the country over of about 10 per cent in metallurgical furnaces. An average of 250 miscellaneous oil burning furnaces gave, actually, a thermal efficiency of 9.2 per cent.

It may be interesting to note that if a good steam-electric plant delivers 12 per cent of the fuel at the bus, and if a super steam-electric plant delivers 19 per cent of the fuel B.t.u. at the bus, then an electric furnace with a thermal efficiency of 80 per cent will in the first case utilize 9.6 per cent of the fuel in useful work, while in the second case it will at the same efficiency deliver 15.2 per cent of the energy of coal burned under the boiler to the charge to be heated. Since the cost of burning coal is less per ton in the central station than in the average fuel furnace for metallurgical purposes, it is evident that electric heat often conserves the coal supply and often may compete with fuel processes without any serious handicap from the B.t.u. cost factor. In some cases where water power is sufficiently available, the lower cost may be on the side of the electrically generated B.t.u.

Electric Heat and Steel Making

Little is definitely known as to details of heating methods used for making the first steel. Authorities in such matters tell us that the melting was done in a crude Catalan forge, which consisted of a bowl formed by the side of a hill and wall. The blast was probably generated through the medium of a clay tube and some skins forming a primitive bellows. The fuel was probably charcoal, and it was mixed with the iron ore and placed in the bowl of the forge. The affinity of the iron for carbon gave a resultant fused mass containing a small per cent of absorbed carbon, making it harder and better for tools.

Aristotle in 250 B. C. describes steel making of that period thus: Iron was first smelted from its ore in Catalan forge, giving

a mass of sponge iron full of slag and cinders in the bottom of the bowl. This sponge was hammered to relieve it so far as practicable of cinders and undesirable material; then broken into small pieces and again melted in a small clay crucible together with small wood chips and green leaves, from which resulted a very fine smooth steel which would take a remarkable fine temper.

We do not know the history of the discovery of tempering this steel, but it was probably accidentally accomplished when a piece of the red hot metal was thrown or plunged in water to cool it more rapidly.

Damascus steel is said to have been a crucible steel and has a peculiarly streaked appearance and nothing has, to date, exceeded it in taking a fine temper. It is not superior, however, over steels of later periods as regards metal cutting.

Huntsman produced the first modern crucible steel in the eighteenth century, and Mushet early in the nineteenth century further perfected the crucible method; then came the modern open hearth, followed by the Bessemer process. Hence for thousands of years, there occurred practically no fundamental changes in methods of steel making. The stupendous advance of the past 50 years in steel making has been associated with the open hearth, and Bessemer process, not to mention the crucible process for high-quality alloy steels. However, perhaps, the most wonderful progress of all has been made in the past decade in uniformity and definite composition and physical characteristics of superquality steel through the intelligent use of the electric melting furnace in the hands of trained metallurgists.

Steel Melting Furnaces

The first steel melting furnace was developed by Siemans in 1882; extensive development was slow until 1915 when records show 213 electric melting furnaces in the world, while in 1920 it is estimated there were a total of 1390 or an increase of 650 per cent in five years.

Electric Heat-Treating Furnaces

It is being rapidly and conclusively demonstrated that electric heat will offer advantages equal to or greater in reheating and general heat treatment of steel, than it has done in melting

and refining. A striking expansion in the use of the electric resistance furnace for the heat treatment of steel is shown in the past five years and progress in the demands of industry is sure, henceforth, to require the "over all" economy and high quality which accompany the use of electric heating for such processes, as, (1) annealing, (2) carburizing, (3) hardening, (4) and tempering or drawing of steels.

It is being daily demonstrated that the electric furnace for reheating, when properly designed and used on steels having uniform characteristics such as may be had from the electric melting furnace, can show an advance in uniformity and quality over the usual steel product of the present day fuel-fired furnace. Furthermore, furnaces are available for any and all tonnage requirements and of such simple and dependable design that their continuity of operation equals that of any fuel-fired furnace, while the low upkeep cost usually is on the side of the electric furnace. To this may be added automatic control of temperatures, duplication of heating cycles, reduction in defective heat-treated parts and usually many other influencing factors which work in the direction of a reduced "over all" cost of production in favor of the electric heat-treating furnace.

The Metallic Resistor Furnace

Important heat-treating processes, in which the metallurgist should be interested, and for which the metallic resistor electric furnace is peculiarly adapted, will be enumerated and briefly described so that the working field for such type of furnace may be clearly indicated. We may, for convenience, consider electric heat-treating furnaces under two heads, viz., (1) those used in production of dies and metal-cutting tools and (2) those employed in the heat treatment of machined, rolled or forged parts.

The production of dies involves the following heat-treating processes: (1) annealing, (2) carburizing, (3) hardening, (4) drawing.

In hardening drop forge die blocks, it is claimed much trouble is obviated by annealing the blocks before performing machine operations on it. Bringing blocks up to the proper annealing temperature at a rate of perhaps 45 minutes for each inch of

thickness, followed by cooling in the furnace, insures against trouble such as warping, checking, cracking or hardening. The proper annealing temperature varies with the carbon content, and the width of the critical range varies likewise.

The committee of the American Society for Testing Materials has recommended the following range in temperatures:

Carbon Content Per Cent	Annealing Temperature Range Degrees Fahr.
Less than 0.12	1607 to 1697
0.12 to 0.25	1544 to 1598
0.30 to 0.49	1399 to 1544
0.50 to 1.00	1454 to 1499

The length of time steel should be held at the annealing temperature varies with the size and shape of the piece. It is important that the piece be heated through uniformly at the annealing temperature. Where quality of output is the watchword, modern heat treatment is not attempted without first carrying out correct annealing treatments as a proper foundation for subsequent processes.

Automatic Temperature Control

With the furnace controlled automatically the perplexing question as to when the steel is heated uniformly throughout is not answered by guess, but it is clearly and definitely shown on the record of automatically controlled temperatures for the annealing cycle. Coupled with this heat control is a furnace atmosphere free from injurious products of combustion, and a heating by uniform radiation rather than by cyclonic convection blasts of hot gases met with in the ordinary fuel-fired furnace.

Forging, forming and cutting dies may be made from (1) high-carbon steels, (0.70 to 0.95 per cent carbon), hardened and drawn, or (2) from low-carbon steel (0.15 to 0.25 per cent carbon) case hardened, the latter virtually eliminating the danger, which exists with high-carbon steel, of spoiled dies, through warping and cracking.

Importance of Quenching

Ancient ideas and processes indicate clearly the fact that early steel treaters attached great importance to the nature of the fluid

in which hot steel was quenched. A work published in 1810 directs one "to take the root of blue lilies infused in wine and quench the steel in it and the steel will be hard." The same author advises that if "the juice or water of common beans have iron or steel quenched in it, it will be as soft as lead." It is said that some barrels of Sheffield water were at one time shipped to America for steel hardening purposes. Pure cold water is now usually employed for hardening. Roughly speaking, steel is glass hard when quenched in ice cold water or brine, and softer when quenched in oil or warm water. In other words, hardness is a function of the rate of cooling, the higher the rate of cooling producing the greater hardness. There are three modern theories for steel hardening, (1) the stress theory, (2) carbon theory, (3) solution theory. The stress theory points to the fact that the cold working of steel hardens it, and contends, therefore, that the high stressing of the cooled outer shell of quenched steel when shrinking upon the hot interior, and the stress of crystal change from hot to cold metal, should also produce hardness. The carbon theory contends hardness results from the carbon content changing its condition from one allotropic form to another during quenching. The solution theory and perhaps the most logical, contends that carbon is in solid solution with the iron, and from such assumption explains all heat-treating phenomena.

All theories concerning hardening, however, are united upon the necessity of heat control as outlined for annealing. Hence the electric furnace, already described as suited to annealing, may be used just as successfully for heating high-carbon steel dies which are to be hardened by quenching. No doubt can exist in the mind of the operator of the electric furnace as to the exact time when the die block, be it large or small, has reached an absolutely uniform temperature throughout. Whence, other things being normal, successful hardening can only be thwarted by improper quenching.

Case Hardening With Electric Furnace

The case hardening applied to low-carbon (below 0.25 per cent) dies is merely the outgrowth of the old cementation process, as used in making crucible steel. Here, however, instead of carburizing the metal through and through, the process ceases after

carburizing to a greater or lesser depth below the surface. The modern case hardening operation is not so simple as the crucible process. A furnace should be available whose heat is easy to regulate and maintain at a fixed uniform distribution during the whole carburizing process. It should be equipped with pyrometer, and automatic regulation of temperature is a valuable asset. Carburization may be effected in several ways but we will restrict ourselves to the pack hardening in boxes containing the carburizing material with which the parts to be treated are surrounded. For practical purposes, work is usually heated to at least 1560 degrees Fahr. and may even be brought to temperatures of 1850 to 1900 degrees Fahr. High temperature gives speed to the process but is objectionable, due to coarsening the grain of the steel and a tendency to distort the work. A good carburizing temperature 1560 degrees Fahr. has the advantage of altering the core but little, unless the process is unduly prolonged. The time of exposure depends upon size of work, depth of carbon penetration desired, per cent of carbon required in the case, carburizing agent used, temperature used, etc. Published tests on a 5/8-inch steel blank, (carbon 0.15 per cent) show the following results of penetration with temperature and a carbon content on the surface of 0.85 to 0.90 per cent with a penetration of 0.050 inches for a particular carburizer:

Time of Exposure in Hours	Penetration in Inches Degrees Fahr.		
	1550	1650	1800
½	.008	.012	.030
1	.018	.026	.045
2	.035	.048	.060
3	.045	.055	.075
4	.052	.061	.092
6	.056	.075	.110
8	.062	.083	.130

High temperature and long exposure tends to render work brittle, partly due to prolonged exposure to high temperature and partly due to relative increase in cross section of hardened area compared to the soft core.

The above remarks lead one to the conclusion that the electric furnace has important advantages for the carburization stage of the case hardening process, where it is evident that close regulation and control of temperature, as well as uniform delivery and

distribution of heat is essential for the best results. Uniformity of product requires that each part of the charge be subjected as nearly as possible to the same heat cycle, whether it be near the center of the carburizing box or near its outer walls. It has already been stated that the electric furnace with its automatic control will bring each part of a charge of material to the same temperature through the control by a surface couple on that charge. Furnaces may be designed to give practically the same heat in each carburizing box constituting the furnace charge, even though the control is actuated from a pyrometer on a single box. In other words, uniform heating conditions exist throughout the heating chamber.

Remarks already made concerning the use of the electric furnace for hardening high-carbon steel dies apply equally to heating for the quench of carburized dies.

Tempering and Drawing

The temper should be drawn on all hammer dies, to relieve strains and to give resiliency or spring resulting in better wearing qualities. An oil-tempering bath electrically heated is a most satisfactory tool, and the hardened dies should immediately go into it even before the die is quite cooled from the hardening operation. Temperature of oil bath should be about 400 degrees Fahr. In other words, hardened steel is "tempered" by being reheated to about 400 degrees Fahr. where it looses considerable brittleness and yet little of its hardness, making it suited for dies, and metal cutting tools; reheated to 480 degrees Fahr. it is less brittle and suited for use in rock drills, stone cutting tools, etc.; at 525 degrees Fahr. it is suited to dental and surgical instruments, hack saws, etc.; at 570 degrees Fahr. the maximum usually employed, it may be used for wood saws, springs, etc. Sudden cooling after tempering does not effect hardness or softness of steel, hence when taken from the oil bath, it way cool either rapidly or slowly.

Electric furnaces for heat treating drop forge dies and metal cutting tools are usually of the box type. There furnaces operate at temperatures up to and including 1800 degrees Fahr. and may be had with automatic control as previously described.

A furnace suited to heating large dies and cutters at temperatures not exceeding 1800 degrees Fahr., with automatic tem-

perature control by test has shown the following performance, compared with a similar oil-fired furnace on the same work.

	Electric	Oil-Fired
Dimensions heating chamber	30"x36"x22" high	48"x24"x20" high
Average temperature held	1450 degrees Fahr.	1400 degrees Fahr.
Fuel or power to hold at 1400 degrees Fahr.	8.04 KWH.	1.65 gal. per hour
Cost per hour to hold 1400 degrees Fahr. at $1.25	$0.10	at $0.14 $0.231
Amount of steel heated per hour	84 pounds	84 pounds
Fuel or power for heating steel	13.35 KWH.	1.9 gal. per hour
Cost fuel or power per hour	$0.167	$0.266
Cost per pound heating steel	$0.199	$0.317

These results may be surprising to those who base their calculations solely on relative B.t.u. costs for oil and electricity. Were the upkeep costs included, the difference in favor of electric furnaces would increase, since in the past four years, the upkeep of this furnace has been practically nothing.

The foregoing has applied to the electric furnace for heating processes in producing drop forge dies and metal cutting tools. A much greater field for the electric furnace lies in the heat treatment of drop forgings. Here we meet again, the annealing, hardning by quenching, case hardening, and tempering or drawing processes. The metallic resistor furnace is here again ready to demonstrate its superiority in heating processes involving 1900 degrees Fahr. or less. The designs of furnaces must comply with methods of handling a production having volume and tonnage. Electric heat can be utilized with practically all types of furnaces, such as car bottom type, pusher type, conveyor type, box or tunnel type, either of vertical or horizontal construction. All furnaces may be well heat lagged without danger to refractories and at the same time secure low thermal capacity resulting in quick heating.

There has been no attempt in this paper to put forth any new heat-treating process. "Well known and accepted process specifications have in part been described only that the completeness with which the electric furnace is able to meet such conditions might be more clearly presented.

The use of the electric furnace does not call for new methods of manipulation of present heating processes, but rather fits itself into standard and generally accepted heat-treating requirements admirably, removing practically all uncertainties connected with proper application of heat; and eliminates almost entirely the handicaps inherent in fuel-fired furnaces. These handicaps of

fuel furnaces have not been discussed here, since it is believed that we are all only too well acquainted with such, due to past forced association.

In conclusion, it may be said that the electric furnace for quality heat treating, is rapidly replacing the fuel-fired furnace. Its simplicity, its dependability, its low upkeep, its improved products, and its ability to turn out repetition work free from defects, are some of the factors which contribute to economy of operation in such a degree that with prevailing rates for electric heat and fuels, the electric furnace usually shows an "over all" cost per piece which is less than that treated in the fuel-fired furnace.

The Human Element

When all has been said and done, the human element may very materially modify results. Attempts should, therefore, be made to take, so far as practical, every opportunity offered to minimize the effect of human manipulation. We refer to such things as perfect conversion of heat, met with in the electric furnace, and the automatic control of power or temperature, which is almost perfectly accomplished in the present day electric furnace.

Hand in hand with the proper selection of furnace for industrial heating processes and coincident with the selection of electric heat energy, should be well worked out specifications covering the best type, its design, size of unit, number of furnaces, their arrangement in the line of production and the grouping of auxiliary equipment, such as transportation, handling, cooling and testing.

The same definite natural laws control cooling as well as heating. Hence for successful results and low "over all" costs, it is important to have the cooling equipment given the same careful design as the heating equipment. Control must be provided, so far as is possible, to maintain required relations between temperature, cycles of heating and cooling, giving due consideration to surface exposed and underlying mass in order to get maximum quality and quantity of production and economical operation.

"Over All" Cost and Management

The effect on "over all" cost due to "form value," etc. of heat sources, (fuels and electricity) are very much veiled in practice

by wide divergence in such economic advantage, depending upon the managerial ability of the users. Under a poor management the most advantageous "form energy" may be wasteful. Electric energy, however, under good management renders substantial returns by virtue of its "form" in many industrial processes.

Progress for the future means better heating equipment; better methods of heating and better means of handling the charge both within and without of the furnace. In order to insure the best equipment let us have competent engineers to select it, then with the best operators to handle the equipment we will realize the minimum for our "over all" costs.

Discussion of Mr. Collins' Paper

MR. TURNER: I would like to ask Mr. Collins as to what price per kilowatt-hour an electric furnace could be compared in cost to a gas-fired furnace, the cost basis, and what cost one would have to buy electric current at to economically operate an electric furnace, as compared with gas.

E. F. COLLINS: I might say that one of the objects in writing this paper was to prevent people from asking that question, because it is a very difficult one to answer directly. In other words, I have pointed out in this paper, that about the last question that you should ask yourself in choosing between the electric furnace and any other type, is the question of the relative cost of B.t.u.s developed electrically and by fuel, because there are so many other considerations usually met with whose economic value is very much greater than the relative cost of B.t.u. generated electrically as compared with fuel, that is a matter of taking average values.

I have in mind one instance in which gas-heated equipment was replaced by electric in which the company could have afforded in that case to have paid 75 cents a kilowatt-hour for the electric energy as against 60-cent gas. That is, of course, an exceptional case, but in my paper, you will see that I have made a plea for a thorough study, analysis and a valuation of the advantages and the disadvantges of the electric as compared with fuel-fired equipment, before deciding which it shall be. I am not an advocate of electric heat for all purposes and in all places. As a matter of fact, some of my hardest fights have been to keep electric heating out of industrial processes where I knew it was not suited. I have always attempted in my recommendations of the electric furnace to be absolutely impartial and to make a study and analysis of the over-all proposition, the over-all cost of the finished product, and then recommend that form of heat which will give the best results considered from all angles.

As an example I recall a case of the heat treatment of a miscel-

laneous lot of dies. These ran in shop costs from perhaps $50 to $100 per die up to $1200 or $1500, and I investigated the total cost of heat treating those dies using electric heat and using oil. I found with the rates prevailing that the electric heat in this instance cost just about double that of oil for doing this work, but I also found that the total cost of the electric energy for doing that heat treating was only 0.006 of the factory cost of those dies. Our experience proved that we might expect from the electrically treated die a production that was 50 to 100 per cent in excess of the oil treated. You see you do not have to make many more punchings from the die electrically heated, to absolutely wipe out the total cost of your electric heat, to say nothing about the difference in cost.

I hope that I have made this clear, and I hope that all of you have an opportunity to read this paper, in which I have called attention to those phases which lie auxiliary to the direct cost of the B.t.u. developed electrically as compared with the cost of the B.t.u. developed by other means.

QUESTION: The main element in the cost of the electric furnace is the metallic type of resistor, and the question resolves itself into the section of resistor metal that one is able to use. I would like to know if you can tell us whether the voltages have been standardized for any type of furnace that would allow us to use a heavier section of metallic resistor?

E. F. COLLINS: Ordinarily the electric furnace should be so designed that there will be no appreciable deterioration of the metallic resistor, and it is possible to so design such furnaces, using the chrome nickel resistor that will carry up to temperatures, if you please, of about 1800 degrees Fahr. Now I don't mean to say, of course, that the deterioration at 1800 degrees Fahr. is no more than the deterioration at 1000 degrees Fahr., but the deterioration of a resistor at those temperatures is very, very slight, and so slight, in fact, that the upkeep of the furnace is usually only a fraction of the upkeep of a fuel-fired furnace of the same capacity and doing the same work.

QUESTION: The question in my mind was whether electric furnaces have been developed to a point where one can decide the proper voltage at which to operate the resistor?

E. F. COLLINS: I think you are a bit confused as to the effect of voltage on the resistor. The voltages which are used are almost universally standard voltages. The amount of heat which is put into a resistor is dependent upon its resistance and voltage applied. You can take the same size ribbon and by making a longer length of it reduce the quantity of heat, but we do run at certain densities, heat densities, on the resistor. A given number of watts per square inch of radiating surface are allowed, and we hold that value of heat

emission, or heat generation, to such a point that at its maximum appreciable deterioration of the resistor does not occur.

QUESTION: I would like to ask if the heating arrangement has ever been made that will take small voltages for heating steel for forging.

E. F. COLLINS: I have in the past operated electric furnaces which heated billets to a matter of 1200 degrees Cent. or thereabouts, but that was a carbon type of furnace which did not prove to be a commercial proposition. When it comes to applying the electric resistor to a forging proposition such as faces us today, we are not ready to talk about that yet.

THE TEMPERING OF TOOL STEELS

By J. P. Gill and L. D. Bowman

Abstract

This paper makes a study of the effect of time, temperature and mass on the tempering of tool steels, including high-speed steels. It is shown that tempering colors are dependent on time as well as temperature, and that all tempering colors can be produced on the surface of a piece of steel successively at low temperatures (250-300 degrees Fahr.) if held for a sufficient length of time. It is also shown that the time element is less effective, the higher the drawing temperature, and that mass has only a small effect upon the rate of tempering.

Molecular rearrangement takes place in hardened steels at atmospheric temperatures, the speed of which increases with the temperature, but is not proportional to the temperature.

The first measurable decrease in hardness takes place in a 1.00 per cent carbon tool steel at a temperature of about 275 degrees Fahr. when tempered for a length of time not greater than two hours. The same is true for a number of light alloy tool steels. As the percentages of carbon and alloys increase, it requires a proportionally higher temperature to soften the steel, until in high-speed steel, tempering within a certain range, actually increases the hardness of the steel. The specific gravity increases and the volume decreases with the tempering of carbon and light alloy tool steels. A number of tempering diagrams are given for some standard types of tool steels.

High-speed and carbon tool steels should be slowly cooled from the tempering temperatures. Quenching from these temperatures will produce some brittleness.

A short discussion is given of the phenomenon of "temper brittleness" as it refers to tool steels.

A paper presented before the fifth annual convention of the Society, Pittsburgh Oct. 8-12, 1923. The authors, J. P. Gill and L. D. Bowman are metallurgists with the Vanadium-Alloys Steel Co., Latrobe, Pa.

PRACTICALLY all steels and more especially tool steels, after they have been hardened, are in a strained condition and oftentimes have excess hardness. To relieve these strains, to decrease the brittleness and hardness, or to toughen, the steel is heated to a temperature considerably below its critical range. This operation is known as "tempering." The tempering of steels, simple as the operation seems, will occasionally produce effects little understood and often unexplainable. Furthermore, the tempering operation does not seem to have been given the study that its importance apparently deserves.

Temper Colors

Until recent years nearly all tempering was regulated by the so-called tempering colors, and we know that this method is still widely used in the tempering of such tools as chisels, etc. There is a fair agreement among steel treaters and metallurgists as to the temperature at which different colors appear on the surface of a piece of bright steel when it is heated.

The following table of temperature colors is the one generally accepted:

Color	Degrees Fahr.
Faint Yellow	430
Straw Yellow	460
Dark Yellow	480
Brown	500
Red Brown	510
Light Purple	530
Dark Purple	550
Blue	560
Dark Blue	570
Pale Blue-Grey	600

These colors are the result of a thin coat of oxide forming on the steel, and just as scale forming on steel at a red heat increases in thickness with time and with the temperature constant, this coat of oxide may be increased in thickness by holding at some temperature a sufficient length of time. Thus, holding a piece of steel weighing about a quarter of a pound at 500 degrees Fahr. for some forty minutes, all the temper colors can be successively produced beginning with the straw color and passing through the entire range to the blue. The following results were produced by

Brearley by heating small pieces of steel with free access to air. The figures, given below indicate the number of minutes. required to produce the full color as tabulated.

Temperature 500 Degrees Fahr.					
Color	Straw	Brown	Purple	Dark Blue	Pale Blue
Minutes	0.5	3	11	27	40

These simple experiments show that the color is as much dependent on the time as the temperature. However, the time element also has effect on the tempering of the steel, and statements have been made that the temper-color bears a true relation to the hardness of the steel regardless of how this temper-color was produced. That is, if a piece of steel shows a brown temper—color by holding at a temperature of 500 degrees Fahr. for ten minutes, and a purple color by holding at the same temperature for thiry minutes, the two pieces of steel will have the same hardness. This may be true for a number of cases, but this rule cannot be generally applied. It is best to consider that the color is only of value as an emperical guide under definite conditions.

Molecular Rearrangement of Hardened Steel

Molecular rearrangement begins to take place in hardened steels immediately after quenching and at atmospheric temperatures, in proof of which is the fact that hardened magnet steels show more constant magnetic properties six months or a year after hardening, than shortly after hardening. Also thin strips of tool steels hardened so that they remain straight, will often times warp six months or more later, though they have not been subjected to temperature changes of more than 20 or 30 degrees Fahr. Molecular changes are usually accompanied by either heat evolution or absorption, and it has been found that hardened steel in returning to its normal state, partially accomplished by tempering, gives off heat. Schottky[1] in his work on tempering steels shows this by placing hardened steels in water vapor, and even at such a low temperature notes that the temperature of the vapor increases several tenths of a degree. He finds that the evolution of heat in-

1. The Metallography and Heat Treatment of Iron and Steel—A. Sauveur, P. 307.

creases with the carbon content up to a certain maximum, and then decreases. This molecular rearrangement is hastened by an increase in temperature and it has been the practice of manufacturers to quickly age their magnets by alternately placing them in boiling and freezing water. Since this molecular rearrangement is hastened by an increase in temperature, we are justified in stating it is tempering, in which case it follows that tempering takes place at atmospheric temperatures.

By holding a piece of hardened 1.00 per cent carbon tool steel ¾ x ¾ x 2 inches at a temperature of 212 degrees Fahr. for eleven days, a slight decrease in hardness took place, and during this time the entire range of temper colors was produced. The effect, however, of low temperature tempering, let us say up to the temperature of boiling water, is chiefly exhibited by the removal of internal strains and brittleness, resulting from the strains.

Tempering for a limited time, that is, two hours or less, the first definitely measurable decrease in the hardness of a hardened piece of 1.00 per cent carbon tool steel takes place in the neighborhood of 275 degrees Fahr. The same is true for most light alloy tool steels. This decrease in hardness is very small and gradual until a temperature in the neighborhood of 500 degrees Fahr. is reached, when the decrease in hardness seems to become slightly more rapid. This rate of decrease seems to remain constant up to a temperature of about 1250 degrees Fahr., when the rate of decrease slackens until the critical point of the steel is reached.

Figs. 1, 2, 3, and 4 show the effect of different temperatures on the hardness of hardened tool steels of four general types. Fig. 1 shows the curve for a straight carbon tool steel containing 1.01 per cent carbon, 0.30 per cent manganese and 0.25 per cent silicon. Fig. 2 shows the curve for a chrome vanadium steel containing 0.71 per cent carbon, 0.74 per cent chromium and 0.21 per cent vanadium. Fig. 3 shows the curve for a steel of the oil-hardening non-deforming type containing 1.03 per cent carbon, 1.09 per cent manganese, 0.48 per cent chromium and 0.18 per cent vanadium, and Fig. 4

shows the curve for a steel containing 1.11 per cent carbon, and 1.25 per cent tungsten.

As the percentages of carbon and alloys in the steel increase, it requires a higher temperature to proportionately

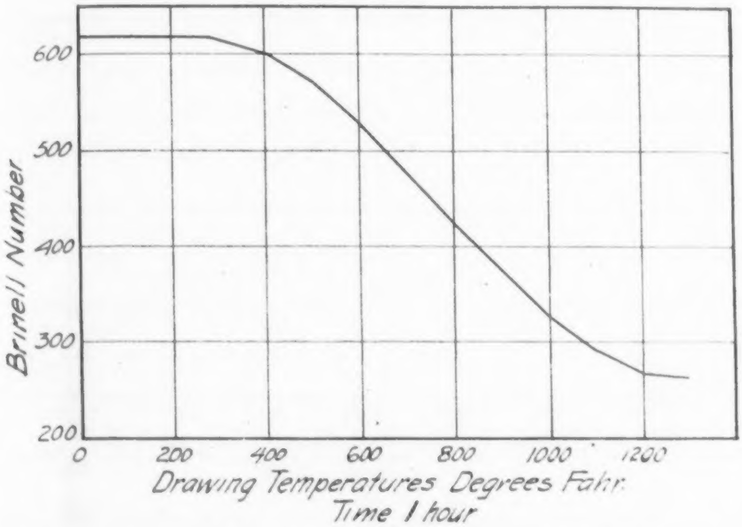

Fig. 1—Curve Showing the Effect of Various Tempering Treatments on the Brinell Hardness of a Hardened Carbon Steel having the following Analysis: Carbon, 1.01 per cent; Manganese, 0.30 per cent; Silicon, 0.25 per cent. Hardened by Quenching in Water from 1425 degrees Fahr.

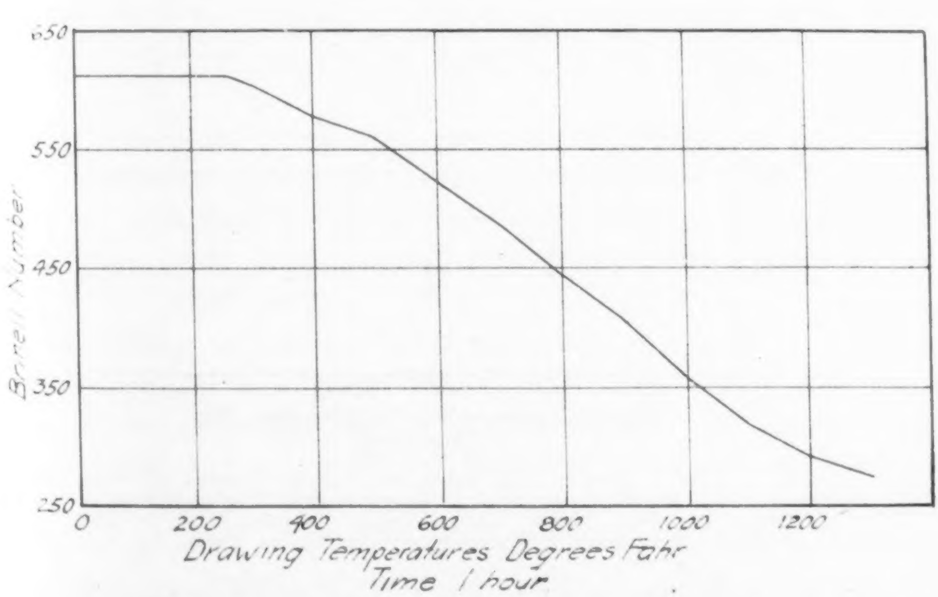

Fig. 2—Curve Showing the Effect of Various Tempering Treatments on the Brinell Hardness of a Chrome-vanadium Steel having the following analysis: Carbon, 0.71 per cent; Chromium, 0.74 per cent; Vanadium, 0.21 per cent. Hardened by Quenching in Water from 1425 degrees Fahr.

soften the steel until the percentage of alloys becomes so great that a pure or nearly pure austentitic structure is produced by hardening. Tempering a steel of this kind within a certain range, will actually increase its hardness. This is

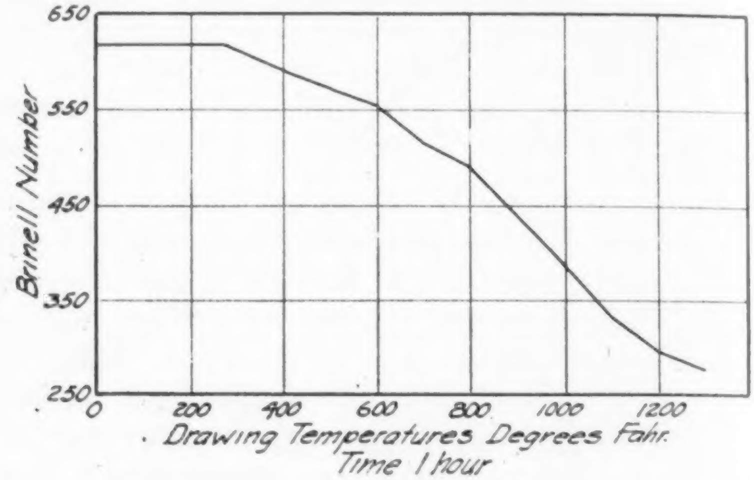

Fig. 3—Curve Showing the Effect of Various Tempering Treatments on the Brinell Hardness of an Oil-hardening Steel having the following analysis: Carbon, 1.03 per cent; Manganese, 1.09 per cent; Chromium, 0.48 per cent; Vanadium, 0.18 per cent. Hardened by Quenching in Water from 1450 degrees Fahr.

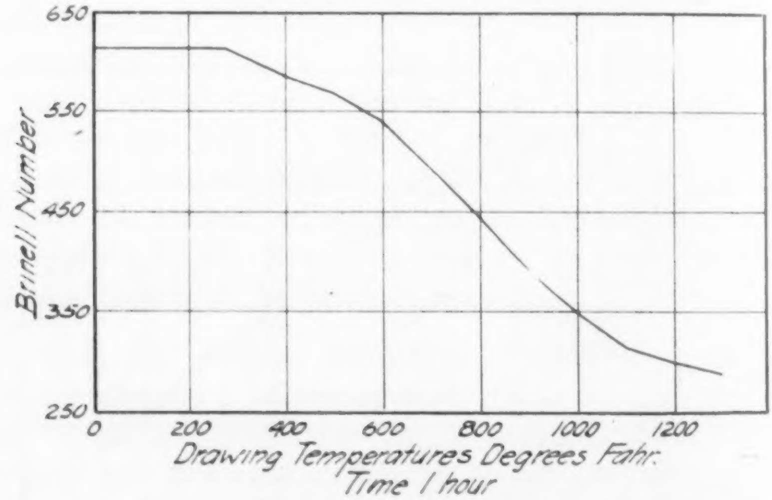

Fig. 4—Curve Showing the Effect of Various Tempering Treatments on the Brinell Hardness of a Tungsten Steel having the following partial analysis: Carbon, 1.11 per cent; Tungsten, 1.25 per cent. Hardened by Quenching in Water from 1450 degrees Fahr.

especially noticeable in high-speed steel that has been properly hardened. The structure before tempering is almost wholly austenitic, but on heating within a certain range the austenite

is changed to martensite, which is a harder structure than austenite. Thus we have an increase in hardness, which is often referred to as "secondary hardness." Fig. 5 shows the effect of the drawing temperature on the hardness of high-speed steel.

The length of time a piece of hardened steel is held at the drawing temperature greatly affects its hardness. This effect becomes less noticeable with a higher drawing temperature, which is apparently due to a combination of causes,

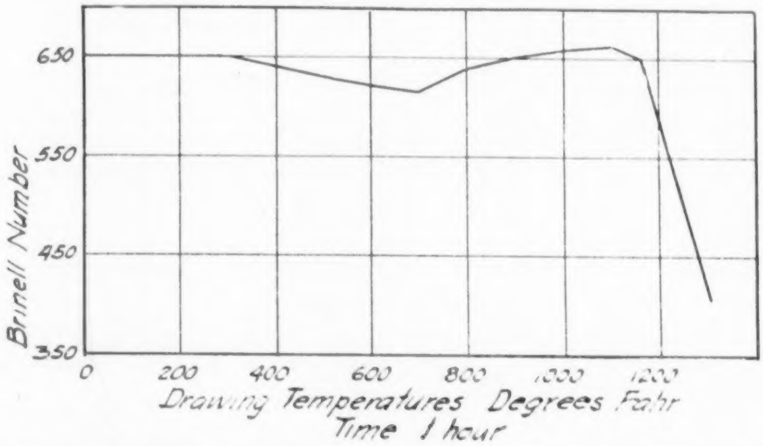

Fig. 5—Curve Showing the Effect of Various Tempering Treatments on the Brinell Hardness of a High-speed Steel Hardened at 2350 degrees Fahr., having an approximate analysis of Carbon, 0.68 per cent; Chromium, 4.00 per cent; Vanadium, 1.00 per cent; Tungsten, 18.00 per cent.

among which are, that the rate of heat penetration into a piece of steel is faster as the temperature increases and also that the time factor has greater possiblilities of demonstration at the lower temperatures, inasmuch as the steel is in its most unstable condition.

According to Barus and Strouhal[2], to each tempering temperature there corresponds a maximum tempering effect which is the more quickly reached the higher the temperature. This is true for all practical purposes since the amount of tempering which takes place in one or two hours after the first four hours of tempering, is exceedingly small. When carrying the length of time to extremes, and drawing for days and even weeks, there is still a slight further decrease

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in hardness. Where this decrease in hardness would stop, cannot be answered. The maximum tempering effect at 350 degrees Fahr. is practically accomplished on a 1.00 per cent carbon steel 1 inch square, in about four hours, this time decreasing rapidly as the tempering temperature increases, so that at a temperature of 1000 degrees Fahr. one hour appears sufficient to obtain the practical maximum tempering effect. Fig. 6 shows the tempering of the same four steels which were

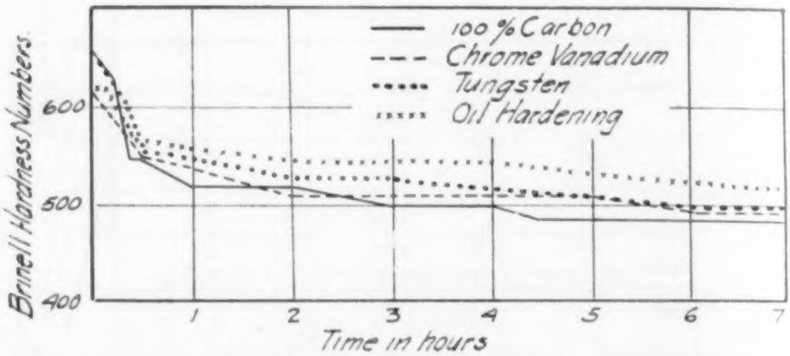

Fig. 6—Shows the Brinell Hardness Curves of the Four Steels of Figs. 1, 2, 3 and 4 when Tempered for Varying Lengths of Time at 600 degrees Fahr.

used for showing the effect of different tempering temperatures, held different lengths of time at a temperature of 600 degrees Fahr.

Effect of Mass on Rate of Tempering

Mass has only a small effect upon the rate of tempering, that is, if the practical maximum tempering effect were obtained at a certain temperature in one hour with a specimen having a volume of 1 cubic inch, it would require practically the same time to obtain the same tempering effect with a specimen of the same steel having a volume of 16 cubic inches. Five different size blocks, each a cube, were made of four types of tool steels. Each set of blocks were so hardened that all had practically the same initial hardness. The specimens were drawn in a liquid bath and held at the actual temperatures given, for the time given. Tables Nos. I, II, III and IV show the results obtained.

Upon the initial hardness of a piece of steel partially de-

pends its hardness after drawing. For instance, a piece of steel of such analysis which can be made file-hard by quenching in water, and showing a Brinell hardness of some 650, let us say will only show a Brinell hardness of 550 by quenching in oil, and by still slower cooling a Brinell of 450. The initial hardness then of these three pieces of steel of the same

Table I

Effect of Mass on the Rate of Tempering an Alloy Tool Steel

	Size of Specimen				
Drawn at	1-inch cube Brinell number	1½-inch cube Brinell number	2-inch cube Brinell number	3-inch cube Brinell number	4-inch cube Brinell number
600 degrees Fahr. for 30 min.	567	567	567	578	578
600 degrees Fahr. for 60 min.	542	542	555	555	555
600 degrees Fahr. for 120 min.	524	524	532	542	532
800 degrees Fahr. for 30 min.	468	477	477	477	477
800 degrees Fahr. for 60 min.	452	460	460	460	460
800 degrees Fahr. for 120 min.	444	452	452	452	452
1000 degrees Fahr. for 30 min.	387	395	402	395	402
1000 degrees Fahr. for 60 min.	364	375	375	364	364
1000 degrees Fahr for 120 min.	351	364	375	364	364

Analysis of Steel

Carbon. 0.72 per cent; manganese, 0.18 per cent; phosphorus, 0.011 per cent; sulphur, 0.012 per cent; silicon, 0.23 per cent; chromium, 0.73 per cent; vanadium, 0.18 per cent.

analysis being respectively 650, 550 and 450 if then drawn to different temperatures, give us results similar to those shown in Fig. 7 ideally made from the results obtained from several different steels.

Volume Changes

Let us next consider the volume changes produced by tempering. Nearly all tool steels expand on hardening. That is, they show a greater volume and lower specific gravity. Though there are steels which may contract on hardening, careful specific gravity measurements of most tool steels will show a lighter material after hardening than before, or that the volume of the steel has increased. Metcalf and Langley[3] have compiled the figures in Table V of the specific gravities for hardened steels of different carbon contents.

From this table it may be stated that the volume of a straight

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carbon steel increases with the carbon content. It would then be expected, and it is true, that tempering carbon and light alloy steels increases their specific gravity, and therefore lessens the volume, or in other words causes them to shrink. Fromme[4] has determined the specific gravity of a rod 0.16 inch in diameter hardened and tempered at various temperatures. Taking the volume of the annealed rod as unity, he obtains the figures shown in Table VI.

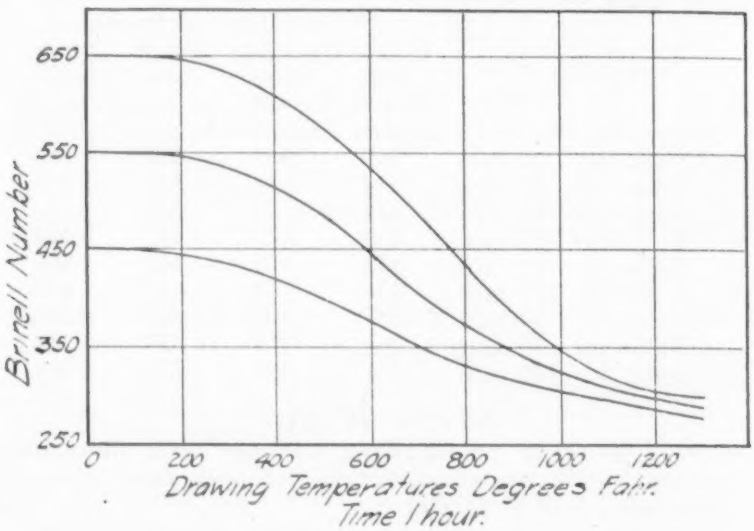

Fig. 7—Curves Showing the Effect of Varying Drawing Temperatures upon the same Composition Steel when Initially Hardened in Mediums yielding Brinell Hardness Figures of 650, 550 and 450, respectively.

Physical Properties

The physical properties of hardened tool steels including the tensile strength, elastic limit, percentage of reduction in area, and the percentage of elongation, are but a poor index to the properties of the steel until they have been given a sufficient tempering, to at least give a low definite figure for reduction in area. This is quite evident since when there is no measurable reduction in area or elongation, the tensile properties of the steel are likely to prove erratic. Thus the physical properties (just named) of hardened tool steels usually have little importance until they have been drawn to a temperature in excess of some 650 degrees Fahr., since at

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this temperature little or no martensite seems to remain in carbon and light alloy steels, and going above this temperature troosite begins to decompose into the constituent characteristic of steels in their toughest state, sorbite. Bullens

Table II

Effect of Mass on the Rate of Tempering an Alloy Tool Steel

	——Size of Specimen——				
Drawn at	1-inch cube Brinell number	1½-inch cube Brinell number	2-inch cube Brinell number	3-inch cube Brinell number	4-inch cube Brinell number
800 degrees Fahr. for 30 min....	532	542	532	542	542
800 degrees Fahr. for 60 min....	524	524	524	532	524
800 degrees Fahr. for 120 min....	512	512	512	524	512
1000 degrees Fahr. for 30 min....	437	437	444	444	437
1000 degrees Fahr. for 60 min....	424	424	430	430	424
1000 degrees Fahr. for 120 min....	402	402	410	410	410

Analysis of Steel

Carbon, 0.98 per cent; manganese, 0.21 per cent; phosphorus, 0.015 per cent; sulphur, 0.013 per cent; silicon, 0.26 per cent; chromium, 4.07 per cent.

Table III

Effect of Mass on the Rate of Tempering a Carbon Tool Steel

	——Size of Specimen——				
Drawn at	1-inch cube Brinell number	1½-inch cube Brinell number	2-inch cube Brinell number	3-inch cube Brinell number	4-inch cube Brinell number
600 degrees Fahr. for 30 min....	567	567	567	555	567
600 degrees Fahr. for 60 min....	542	555	567	542	555
600 degrees Fahr. for 120 min....	532	542	555	542	542
800 degrees Fahr. for 30 min....	452	452	460	460	452
800 degrees Fahr. for 60 min....	437	444	437	452	444
800 degrees Fahr. for 120 min....	430	437	430	444	437
1000 degrees Fahr. for 30 min....	382	387	382	382	387
1000 degrees Fahr. for 60 min....	346	357	351	346	351
1000 degrees Fahr. for 120 min....	340	351	351	346	346

Analysis of Steel

Carbon, 1.04 per cent; manganese, 0.23 per cent; phosphorus, 0.017 per cent; sulphur, 0.008 per cent; silicon, 0.26 per cent.

designates the temperatures lying between 750 and 1250 degrees Fahr. as the toughening range of steel, and it is steels tempered only in this range upon which we will consider the effect of the tempering on the physical properties. Each increase in temperature in this range lowers the tensile strength and elastic limit, but with a corresponding increase

in the ductility. The ratio of the tensile strength to the elastic limit remains quite constant until a temperature of about 1300 degrees Fahr. is reached, when the elastic limit begins to decrease faster than the tensile strength, the greatest difference resulting in the annealed steel.

Temper Brittleness

Further consideration of the physical properties to include the impact strength brings us to the discussion of a phenomenon which at present is unexplainable. This phenomenon is the "temper brittleness" of steels.

Table IV

Effect of Mass on the Rate of Tempering a High-Speed Tool Steel

	——Size of Specimen——				
Drawn at	1-inch cube Brinell number	1½-inch cube Brinell number	2-inch cube Brinell number	3-inch cube Brinell number	4-inch cube Brinell number
1200 degrees Fahr for 30 min	591	600	591	600	600
1200 degrees Fahr. for 60 min	578	578	578	591	578
1200 degrees Fahr. for 120 min	542	555	555	578	555
1300 degrees Fahr. for 30 min	402	402	402	402	...
1300 degrees Fahr. for 60 min	375	382	370	382	...
1300 degrees Fahr. for 120 min	364	364	370	375	...

Analysis of Steel

Carbon, 0.69 per cent; manganese, 0.21 per cent; phosphorus, 0.022 per cent; sulphur, 0.003 per cent; silicon, 0.23 per cent; tungsten, 18.20 per cent; chromium, 4.13 per cent; vanadium, 1.15 per cent.

Table V

Specific Gravity of Steels Having Different Compositions

Percentage of Carbon	Sp. Gr. of the ingot	Sp. Gr. of the annealed bar	Sp. Gr. of the steel hardened at a red heat	Sp. Gr. of the steel hardened at a yellow heat
.529	7.841	7.844	7.826	7.814
.649	7.829	7.824	7.849	7.811
.841	7.824	7.829	7.808	7.784
.871	7.818	7.825	7.773	7.755
1.005	7.807	7.826	7.789	7.749
1.079	7.805	7.825	7.798	7.741

In the investigations[5] of material for the construction of airplanes and airplane engines by the British government, Brearley called their attention to the "temper brittleness" phenomenon which occurred particularly in chrome nickel

5. Report on the Materials of Construction Used in Aircraft and Aircraft Engines—P. 23.

steels. This phenomenon exhibited itself to a high degree in a steel containing 0.33 per cent carbon, 3.71 per cent nickel and 0.91 per cent chromium. By hardening this steel and then tempering to 1200 degrees Fahr. and cooling slowly, it gave an Izod impact value averaging only four for a number of samples. Instead of cooling slowly from 1200 degrees Fahr.

Table VI

Specific Gravity of Rod Hardened and Tempered at Various Temperatures

Condition of rod	Volume of rod 0.16 inch in diameter
Annealed	1.00000
File hard	1.01000
Tempered at yellow	1.00492
Tempered at blue	1.00425
Tempered at grey	1.00060
Tempered very high	1.00055

Table VII

Izod Impact Tests on Standard V-Notched Bars

The bars were heated to 1200 degrees Fahr. for 30 minutes, cooled to and quenched in water from the temperatures shown in each column. The results are given in foot-pounds.

Analysis of steels tested	1200 degrees Fahr.	1050 degrees Fahr.	900 degrees Fahr.	750 degrees Fahr.	600 degrees Fahr.
1.00% C, .005% S .31% Si, .02% P .23% Mn, .00% Cr	9	8	9	13	14
.51% C, .010% S .31% Si, .015% P .30% Mn, .80% Cr .21% Va	52	62	64	77	79
.71% C, .012% S .33% Si, .011% P .18% Mn, .73% Cr .17% Va	66	72	73	82	82

but by quenching in water from this temperature, the average Izod impact number was 48, or twelve times the figure obtained by slow cooling, while at the same time the other physical properties remained the same. This so-called "temper brittleness" was not noticed until the steel was tempered to a temperature in excess of 750 degrees Fahr. and showed its greatest effect when the steel was tempered to 1100 degrees Fahr. Fig. 8 shows this effect exhibited in another nickel-chrome steel. The steel was first hardened, then tempered

to 1200 degrees Fahr. and then slowly cooled to the temperature shown, and quenched in water from these temperatures. This phenomenon was further investigated by others and reported on at the fall meeting 1923 of the British Iron and Steel Institute, by Rogers and Greaves in two separate papers. Rogers reported that "temper brittleness" existed in low carbon steels, nickel steels and chrome vanadium steels.

The authors of the present paper have extended this investigation to several types of tool steel. A number of speci-

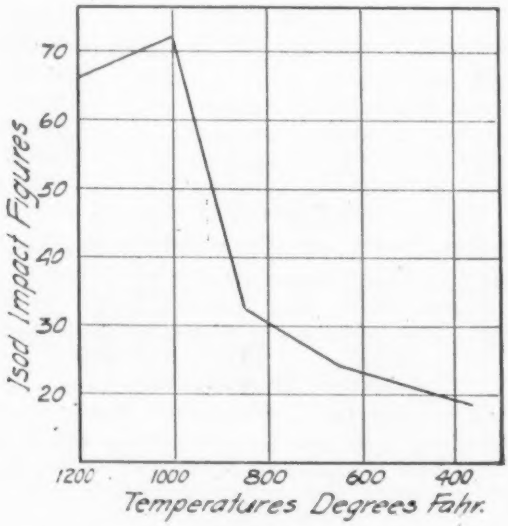


Fig. 8—Shows the Effect of Temper Brittleness upon the Izod Impact Values of a Nickel-chromium steel.

mens were made according to the Izod standard, that is, 10 millimeters square with a V-notch 2 millimeters deep, having a small radius at the bottom. All the specimens of each type of steel were hardened as nearly as possible under identical conditions. The different lots of specimens were drawn and quenched with the results as shown in Tables VII and VIII. It will be seen from these results that not one of the steels exhibited "temper brittleness," and a preliminary investigation of a number of other tool steels showed similar results. Furthermore, Table VIII shows that quenching from the drawing temperature in most cases gave lower impact values. Six specimens of an 18 per cent tungsten high-speed steel $\frac{5}{8}$ inch square, were hardened under the same conditions

from a temperature of 2325 degrees Fahr. and drawn to 1100 degrees Fahr. for twenty minutes. Three of the specimens were slowly cooled and the others quenched from the drawing temperature. Following are the average impact results obtained:

Cooled Slowly	Quenched in Water
83	68

From these results, it is evident that both high-speed and carbon tool steels should be slowly cooled from the drawing temperature.

Tools should be tempered as soon as possible after hardening, and should be heated uniformly and slowly during the tempering operation, this being more especially true if the tool is complicated and has thin sections and sharp projections.

Table VIII
Izod Impact Tests on Standard V-Notched Bars

Upper row of figures are the results obtained by heating to and quenching in water from the temperatures shown.

Lower row of figures are the results obtained by heating to and cooling slowly from the temperatures shown.

Analysis of steels tested	1200 degrees Fahr.	1050 degrees Fahr.	900 degrees Fahr.	750 degrees Fahr.	600 degrees Fahr.
1.00% C, .31% Mn, .25% Si..	9	5	4	4	3
.005% S, .02% P, .00% Cr..	12	8	6	4	2
.51% C, .31% Si, .30% Mn..	52	33	20	10	13
.010% S, .015% P, .80% Cr..	76	44	25	14	10
.21% Va					
.71% C, .33% Si, .18% Mn..	66	58	12	4	..
.012% S, .011% P, .73% Cr..	82	57	18	3	..
.17% Va					

Tempering Methods

Tempering methods are quite varied, and many may have their usefulness. The use of the tempering plate made of cast iron and heated from beneath, and the judging of the tempering of the tool from its color, is a very old method and one which is not any too exact. The sand bath method of packing the tools in sand in a suitable container and measuring the temperature of the sand with a thermometer or thermo-

couple, is reasonably satisfactory. It seems, however, that the liquid bath method is for general tempering work, the best. The liquid used depends on the temperatures necessary. Oil may be used up to a temperature of 500 degrees Fahr., and somewhat higher, as mineral oil can be obtained having a flash point of 600 degrees Fahr. For temperatures between 450 and 1000 degrees Fahr. a mixture of two parts KNO_3 and three parts $NaNO_3$ may be used. For temperatures from 650 to 1500 degrees Fahr. lead may be used, or by adding eight parts of tin or antimony to fourteen part of lead, it becomes liquid at 420 degrees Fahr. The liquid should be placed in a suitable container preferably one well insulated, and should be heated by some method that is uniform and easy of control. A wire basket should be provided and the pieces to be tempered placed in it and the whole lowered into the liquid, which should be at a reasonably low temperature. The whole should then be heated to the tempering temperature. This is much better than having the bath at the desired tempering temperature, and then suddenly placing the tools in it. This sudden heating tends to produce new stresses which must in turn be overcome.

Discussion of Messrs. Gill and Bowman's Paper

CHAIRMAN MERTEN: Gentlemen, we now have this paper entitled the *Tempering of Tool Steel,* open for discussion.

MR. TURNER: I would like to ask the speaker whether there would be any difference on the drawing of high-speed steel, between the regular tungsten and the cobalt steels; he showed there the highest hardness at about 1500 degrees Fahr.; now would a cobalt high-speed steel show any change at the same temperature?

J. P. GILL: The tempering diagram of a cobalt steel is practically the same as an 18 per cent tungsten steel.

MR. TURNER: You would, therefore, figure on the same drawing, for both?

J. P. GILL: Yes.

A. H. d'ARCAMBAL: Messrs. Gill and Bowman have shown quite clearly that the low tungsten type of tool steel, that is, a 1.25 or 1.5 per cent tungsten type, resists tempering no better than does the plain carbon type of tool steel.

It might be of interest to say that some small tool manufacturers have put on the market, taps made of this 1.25 per cent tungsten tool steel and called them semi-high speed steel taps. This is a misnomer, because

such tools have absolutely no more high-speed properties than does a plain carbon tool steel tap. Moreover, the majority of the low tungsten tool steels on the market contain about one-half of one per cent chromium, and this means that the steel will resist tempering at a lower temperature than the plain carbon tool steel. For example, tools made of plain carbon tool steel drawn to 400 degrees Fahr. are practically file hard, that is, drawn to temperature and then taken out of the bath, whereas tools made of this low tungsten one-half of one per cent chromium tool steel, can be filed without difficulty when drawn to the same temperature in the same manner.

I would like to ask Mr. Gill what experience he has had in tempering high-speed steel for various periods of time at approximately 1100 degrees Fahr. If a tool were file hard after being drawn for 30 minutes at 1100 degrees Fahr. would it still be file hard when drawn at 1100 degrees Fahr. for one hour, two hours, three hours, etc.?

J. P. GILL: We tempered steels for periods of one week and did not find a decrease in file hardness. It seemed, however, that from one-half to one hour the maximum effect was obtainable.

A. H. d'ARCAMBAL: I believe in Table V you showed that heating to 1200 degrees Fahr. and then cooling slowly to 1000 degrees Fahr. and quenching, you obtained a higher impact value than you did when quenching directly from 1200 degrees Fahr. How did the tensile properties compare on the two?

J. P. GILL: We did not obtain the tensile properties. However, it is likely there would be little difference. The results reported by Harry Brearley show practically the same tensile strength for specimens that showed temper brittleness as for those of the same analysis, not showing this phenomenon.

A. H. d'ARCAMBAL: Would it not be good practice, then, to obtain greater toughness by cooling down slightly before quenching, so as to increase the impact value without changing the static tensile properties?

J. P. GILL: For a tool steel, it would.

A. H. d'ARCAMBAL: You obtained these results on chrome-vanadium, S. A. E. 6150 steel, did you not?

J. P. GILL: All of the chrome-vanadium steels we tested were more brittle when quenched from the drawing temperatures than when cooled slowly. By cooling slowly is meant cooling freely to room temperature without an air blast and also without burying in any insulating medium.

CHAIRMAN MERTEN: The test bar used for the impact test was a standard notched bar, was it not?

J. P. GILL: It was a notched bar.

CHAIRMAN MERTEN: Probably some of your results that showed a failure on quenching from the higher heat could be attributed to the notched bar.

J. P. GILL: We took an average of several tests.

CHAIRMAN MERTEN: Would you find the same results on a solid bar?

J. P. GILL: We used a solid bar ⅝ inch square for the high-speed steels and obtained similar results.

A. L. DAVIS: Since your test was largely confined to drawing temperatures of 650 degrees Fahr. and above, you were in a range higher than that generally used in tempering plain carbon tools, and hence you cannot draw any conclusions as to that. Nevertheless, it occurs to me that the figures that you report for 650 (or perhaps in some cases the next higher temperature) did have a trend for the quenched samples to show up better than the slowly cooled ones; that is, they would show 3 as against 2. Getting it down so small, perhaps it is difficult to draw conclusions, anyway,—but do not your figures suggest a tendency in such steels, when drawn at the lowest temperatures, to develop temper brittleness?
drawn at the lowest temperatures, to develop temper brittleness?

J. P. GILL: No, I can not say that they did. At the lower drawing temperatures most of the steels were file hard and consequently broke very sharply when struck. Therefore, a difference of one or two points, with the impact value so low cannot indicate much. If temper brittleness should exist in tool steels, we would expect to find it somewhere between 600 and 900 degrees Fahr., but this was not the case.

A. L. DAVIS: Was it not a fact that in almost every case at the 650-degree draw, a slightly lower strength was shown than on the slowly cooled pieces.

J. P. GILL: Yes, there was a slight difference, but so little we did not attach any importance to it.

W. D. FULLER: You say that you distinguished a decrease in hardness in the metal drawn at 212 degrees Fahr.?

J. P. GILL: Yes, after 11 days. We kept the specimens in a thermostat at 212 degrees Fahr. and removed the specimen once every 24 hours to measure the hardness.

A. H. d'ARCAMBAL: We have found that a one-half per cent chromium tool steel drawn for about 8 hours at 212 degrees Fahr. can be filed without much difficulty. A plain carbon tool steel drawn for the same time will be file hard after the test, showing that chromium tends to produce tempering at a lower temperature.

PROF. O. W. ELLIS: It has been clearly indicated that a decrease in hardness occurred. It appears that some work is required to connect up the rate of cooling of steel with the subsequent hardness on tempering. A large number of experiments have been carried out, which have shown that test pieces of approximately the same size as those dealt with by Mr. Gill, increase in hardness at the low drawing temperatures. Take for example, the work of Brinell, reported to the Iron and Steel institute in 1901—work that is probably the most exhaustive on heat treating that has ever been carried out—I think that in practically every instance he discovered an increase in tensile strength to occur on drawing subsequent to water quenching and a decrease in tensile strength on drawing sub-

sequent to oil quenching. It appears that some connection needs to be made between, first, rates of quenching, second, hardness subsequent to quenching, and third, hardness subsequent to tempering after varying rates of quenching.

J. P. GILL: The specimens were hardened according to the recommended treatment for hardening the steel when it was to be used for tools and dies. No attempt was made to harden the steel by unusual methods to obtain an austenitic structure which would, of course, first show an increase in hardness when drawn.

J. W. SMITH: All these tests were conducted in an oil bath, as I understand it.

J. P. GILL: Some with oil, others with salt and lead. For the low temperatures we used oil, and above 650 degrees Fahr. we used salt or lead.

H. J. FRENCH: I have been much interested in Mr. Gill's paper, and I assume that he has used in all cases a hardening practice similar to that which is customarily used in practice in hardening the various steels. However, the discussion which has taken place appears to me to make desirable some mention of the fact, that the characteristics of the hardness-tempering temperature curves for tool steels are largely dependent upon the original hardening treatment given the steel of a given composition and given size. For example, a one per cent carbon steel, which is hardened from a temperature such as is customarily used in practice, may show a decrease in hardness with rise in tempering temperature; however, if that steel is heated to a high enough temperature and then quenched, we may get at first, increase in hardness with rise in tempering temperature.

I noticed in the charts which were shown here today the original hardening treatments were not specified. I assume, of course, that in the manuscript those are given in detail. One chart was shown having three hardness-tempering temperatures curves. I think one began at 650, another began at 450, another one at a lower hardness. I did not understand whether that was to represent the effect of mass or whether it was to represent experiments relating to the effect of the original cooling medium. Of course, the two of them are more or less interrelated.

J. P. GILL: It was to show the effect of drawing on samples of the same analysis having a different initial hardness, this hardness produced by the rate of cooling.

H. J. FRENCH: If a one per cent carbon steel is hardened in water, the ratio of the elastic limit to the tensile strength is very much greater than the same elastic ratio when the steel is quenched in oil, even though comparisons are based upon a fixed tensile strength or hardness value, or a fixed elastic limit value. I think that point is rather important in relation to this question of brittleness.

J. P. GILL: Yes, it is.

A. H. d'ARCAMBAL: Have you ever conducted tensile tests on ¼-inch

diameter carbon tool steel wire, quenched in oil as compared with brine quenched specimens?

J. P. GILL: No.

A. H. d'ARCAMBAL: Both treatments will give file hard specimens. I was wondering how the toughness values would show on such specimens.

H. J. FRENCH: At the close of the World war there was appointed under the National Research council a committee which was first known as a Blue Heat committee. This committee was concerned with a study of the so-called temper brittleness or "Krupp Krankheit" of structural carbon and alloy steels. In looking over Mr. Gill's charts I find that the highest impact values were in all cases, or nearly all cases, obtained on a slow cool from the draw. As I remember the results obtained by this committee, not particularly in their own tests, but in summarizing the work of other investigators, they found in a majority of cases that the highest impact values were obtained in samples which were quenched from the drawing heat.

However, several cases came up, or came to their attention, where results consistent with Mr. Gill's results were shown, that is, the slow cool gave the highest impact values. I would like to ask Mr. Gill whether in his experience he has found that the slow cool or the quench from the drawing heat gives the highest impact value, or whether the question has been settled?

J. P. GILL: Our investigation was absolutely in the field of tool steels. We did not attempt to investigate the steels which Brearley and others report as showing the phenomenon of temper brittleness. The tool steels which we investigated, nearly all of which could be made file hard by ordinary hardening methods, showed a lower impact value by quenching from the drawing temperature. We do not believe there is any doubt but that many steels particularly of the chrome-nickel type are tougher by quenching than by slow cooling.

H. J. FRENCH: Is there a possibility that the higher impact values on the slow cool are a result of the longer time at which the sample is hot, although not at a constant temperature?

J. P. GILL: That is possible; but not likely to have had a marked effect since all the specimens were held at the drawing temperature for 30 minutes before cooling.

QUESTION: Is there any relative metallographic constituent present in each of those steels that will give a minimum temper brittleness and a minimum impact value?

J. P. GILL: We were not able to locate any.

CHAIRMAN MERTEN: Temper brittleness is usually connected with a brittleness at some lower temperature than Mr. Gill employed; 600 or 700 degrees Fahr., is the brittle range, and not 1100 or 1200 degrees. I believe that has considerable to do with the results obtained.

J. P. GILL: We report from 600 to 900 degrees Fahr. as the range.

J. STRAUSS: Small variations in hardness have a very great effect

upon the impact value of hard steel, and I just wonder whether Mr. Gill has checked up the results that he has shown for slow cooling as against rapid cooling in order to see what changes in hardness have occurred, and whether such changes, if they occurred, have not a definite relation to the increase in his impact values.

Another point is that it is really not fair to compare one heat of one steel, that is, of one composition, with another single heat of another composition. Heats of steel even made by the same process, depending upon how that process has been carried out, will show impact values which differ very widely, even under the same conditions of mechanical and thermal treatments, etc.

J. P. GILL: Hardness tests made on the specimens slowly cooled and the specimens quenched showed the same. We also took an average of a number of specimens.

J. STRAUSS: I was thinking not of a number of specimens from the same heat, for melting and rolling conditions will change from heat to heat, but of different heats of steel of the same analysis. That may have a very important effect upon the impact value as determined by the Izod test.

J. P. GILL: The results were similar for a number of steels of widely different analyses, and since these results were similar, we would hardly expect different results from steels of like analyses but of different heats.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment — Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions

NEW QUESTIONS

QUESTION 102. *How can the warping of high-speed steel tools be eliminated during the hardening operation?*

QUESTION 103. *What is the effect of clay luting on alloy carburizing boxes?*

QUESTION 104. *In the forging of ring gears, does the number of blows of the hammer have any effect upon the warpage of the gear in the hardening operation?*

QUESTION 105. *Through what mechanism does vanadium retard the penetration of hardness in vanadium steels in the hardening operation?*

QUESTION 106. *What are the effects of the products of combustion upon both carbon and high-speed steel, when heat treated in open furnaces heated with city gas, coal, coke, fuel oil, etc.*

ANSWERS TO OLD QUESTIONS

QUESTION NO. 67. *What is the reason for the fact that a piece of steel quenched in brine will be harder than the same piece of steel would be if quenched in water, providing that the quenching temperatures and quenching medium temperatures are the same in each case?*

ANSWER. By James Sorenson, metallurgical engineer, the Four Wheel Drive Auto Co., Clintonville, Wis.

Greater hardness is obtained from quenching at the same tem-

perature in salt brine than from quenching at the same temperature in water. This is due to the difference in the heat dissipating power possessed by these substances.

Brine produces rapidity in quenching and consequently maximum hardness. However, cold brine should not be used for quenching thin pieces of complicated design, as the shock from so drastic quenching mediums is liable to cause serious distortion, or cracks which would render the piece being heat treated useless.

QUESTION NO. 69. *Is sulphur up to 0.10 per cent detrimental to the quality and physical properties of an automotive steel?*

QUESTION NO. 72. *What elements are conducive to good electric butt-welding of steels?*

QUESTION NO. 73. *Does electric butt-welding destroy the physical properties developed in a steel which has been heat treated prior to the welding operation?*

QUESTION NO. 74. *Why shouldn't a bar of steel rolled from a locomotive axle be better than one rolled direct from the billet made from the original ingot?*

QUESTION NO. 83. *In annealing high-carbon tool steel in an open-fire furnace 6′ x 12′ is it likely that sulphur would be imparted to the steel by the use of producer gas made from coal unusually high in sulphur, say around 1.50 to 2.00 per cent?*

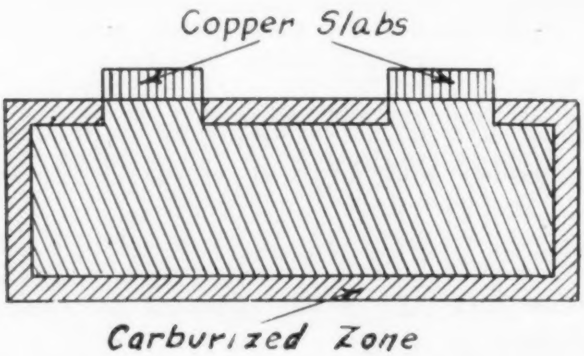
QUESTION NO. 85. *What is the best method of preventing carburization in holes, or in the bore of parts to be case hardened?*

ANSWER. By W. J. Merten, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

The protection of iron and steel by copper plating against

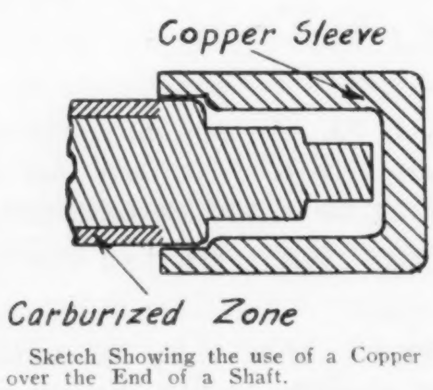
absorption of carbon from carbonaceous gases is only partially successful, due to the porosity of the copper deposit, its tendency to flake, its variation and limit of thickness, and the cost to protect the rest of the part from copper plating.

The placing of solid copper bodies against surfaces or into holes to be left uncarburized, has been found to inhibit carburization very effectively.



Sketch Showing the Manner in which Copper Slabs when placed upon a Steel Block, Prevents Carburization.

A loosely fitting, pure copper pin (1/64 inch loose or even more) can be relied upon to give proper protection and the line of demarcation of area or zone of activity of carbon monoxide gas is quite sharp. External copper sleeves or caps ⅛ inch thick placed over ends of cam shafts and automobile parts have proven very useful. One-quarter inch thick blocks of pure copper placed or laid on plates or die surfaces were entirely successful in preventing any creeping of the carburized portion. Copper



Sketch Showing the use of a Copper Cap over the End of a Shaft.

probably absorbs CO and its presence induces negative catalysis, preventing formation of Fe_3C or possibly interaction of Fe and C.

A large number of tests have been made verifying the utility of solid copper bodies in this respect. The copper is also perpetually recuperating, discharging the absorbed gases on cooling and reheating, so that on standard work it can be used continuously, over and over again.

QUESTION NO. 92. What is meant by reduction of area in tensile testing of metals?

ANSWER. By James Sorenson, metallurgical engineer, the Four Wheel Drive Auto Co., Clintonville, Wis.

The reduction of area in a tensile test specimen refers to the area at the point of rupture, it is usually expressed in percentage. The percentage of reduction of area is found by dividing the difference between the original cross section of area before fracture and the least cross section of area at the point of fracture, by the original cross section of area.

It is usually used as a measure of the ductility of the material and many engineers regard the reduction of area as more reliable for this purpose than the elongation.

QUESTION NO. 93. What are the more common methods of quenching ordinary taps? Are they quenched all over and the shanks drawn, or are they quenched only on the threaded portions; or are both the threaded portions and the tangs quenched, leaving the center portion of the shank soft?

QUESTION NO. 95. What is meant by "self-hardening" steels?

ANSWER. By James Sorenson, metallurgical engineer, the Four Wheel Drive Auto Co., Clintonville, Wis.

The term self-hardening steel usually refers to high-speed steel of the cementitic class, which if heated to the proper hardening

temperature and then allowed to cool in air will retain the dissolved carbides in the martensitic condition.

QUESTION NO. 96. *Can the structure of a piece of steel be determined by the microscope applied to the fracture of a cross section, without polishing and etching the fracture, say of a stamping die 6 x 2 x 3½ inches, that has been hardened and broken in half, that is, are the different structural phenomena known as austenite, martensite, sorbite, ferrite, etc., so determinable?*

QUESTION NO. 97. *What degree of heat is required to change austenite to martensite, troostite, etc?*

ANSWER. By James Sorenson, metallurgical engineer, the Four Wheel Drive Auto Co., Clintonville, Wis.

This is a question on which it may be rather difficult to give a definite answer as the exact nature of martensite has not been definitely settled, but the opinion usually held is that martensite is a solid solution and there is considerable evidence available which seems to justify this opinion. According to Professor Albert Sauveur[1] all the austenite in austenitic steel is converted into martensite at 200 degrees Cent., and at 400 degrees Cent. all the martensite is converted into troostite. At 600 degrees Cent. all of the troóstite is converted into sorbite.

QUESTION NO. 98. *What heat treatment will give a pure martensite structure throughout the hardened area of a piece of steel 6 x 2 x 3½ inches?*

QUESTION NO. 99. *What is the effect of barium carbonate and sodium carbonate in carburizing compounds, on alloy carburizing boxes?*

QUESTION NO. 100. *What action results from the addition of varying amounts of aluminum and ferrosilicon to steel while casting?*

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1. See the Metallography and Heat Treatment of Iron and Steel by Professor Albert Sauveur, 1916, page 300.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

THE INHERENT EFFECT OF ALLOYING ELEMENTS IN STEEL. By E. D. Saklatwalla, *Transactions,* American Electrochemical society, 1923.

This paper is a general discussion of the possible physico-chemical effects of the elements usually added to steel to make commercial alloy steels.

ELECTRIC WELDING OF CAST IRON. By Lebrun in *Revue de Metallurgie,* No. 20, page 248, 1923.

This article states that in order to obtain a satisfactory electric weld of gray cast iron, means must be provided for continuous addition of carbon to replace that burnt by the arc; otherwise the weld would be transformed into white cast iron. Photomicrographs of both etched and unetched welds are shown.

SOME MECHANICAL PROPERTIES OF A SERIES OF CHROMIUM STEELS. By Charles R. Austin, University college, Swansea, in *Journal* Iron and Steel institute, (advance proof), May, 1923.

This paper was presented before the London meeting of the Iron and Steel institute, May 10-11, 1923, and is a record of the effect of heat treatment on the mechanical properties of a series of chromium steels, consisting of two groups, of steels containing about 0.35 per cent carbon and 1.00 per cent carbon respectively, the chromium content varying from 2 to 12 per cent. The author brings out the point that it is very difficult to form a definite conception of the quantitative effects of chromium on the physical properties, due to the continued variation in the amount of carbon present.

STRAIN AND FRACTURE IN METALS. By W. Rosenhain in *Chemical and Metallurgical Engineering,* No. 28, page 1026 (1923).

In this article the author discusses a method for distinguishing shock fractures, as well as a remedy for season cracking. Consideration is also given to the proper manner of increasing endurance of metal to alternating stress.

NEW FURNACE FOR MALLEABLE CASTINGS. By Alfred Gradenwitz in *Iron Age,* Vol. III, page 1782 (1923).

The author of this paper described a 2-ton open-hearth furnace, developed in Switzerland by Edwin Bosshardt. Beside the usual regenerative

system, there is a narrow slot opening from the hottest zone of the adjoining gas producers directly into the furnace hearth. This gives early ignition and a very high temperature, which, using the basic process, yields low-carbon steel of high purity, suitable for thin and complicated castings, or for use where high malleability is needed.

THE RELATION AMONG TENSILE STRENGTH, HARDNESS AND COMBINED CARBON IN INGOT IRON. By Emil Schuz in *Stahl und Eisen*, No. 43, page 820 (1923).

This paper discusses in general the different effects of carbon content and heat treatment. The carbon-iron mixtures are also considered and plotted with the idea of establishing certain formulas.

EXPERIMENTS ON GRAIN GROWTH IN IRON AND STEEL. By L. E. Benson and F. C. Thompson in *Journal* of Iron and Steel institute (advance proof), May 1923.

This article deals with only a portion of the problem confining its formation to temperatures not exceeding 800 degrees Cent., and deals with the influence of the composition only as far as carbon and manganese are concerned.

The steels were chosen so as to include a series in which the carbon and the manganese varied separately, in order that the effect of these elements on the grain size and the rate of grain growth could be observed. The results are given in the form of curves.

GRAPHITE CONTROLS GRAY IRON. By J. W. Bolton in *Foundry*, No. 51, page 405, 1923.

The author states that the size of graphite flakes influences the quality; also that high-carbon irons are sometimes stronger than iron of low carbon. The need of standard testing methods and research on fundamental principles is shown.

PERMALLOY, AN ALLOY OF REMARKABLE MAGNETIC PROPERTIES. By H. D. Arnold and G. W. Elmen in *Journal* of the Franklin Institute, No. 195, page 621, 1923.

This paper states that permalloy is a generic name for a group of alloys of nickel and iron containing more than 30 per cent of nickel. When properly heat treated, these alloys possess remarkable magnetic purposes, that is, high initial permeability. To attain the maximum initial permeability, cooling must occur through the proper temperature ranges and at the proper rate. The best composition for the alloy is approximately 78.5 per cent nickel and 21.5 per cent iron. After heat treatment, this alloy shows better magnetic qualities than iron.

INGOT STRUCTURE AND HEAT TREATMENT. By B. D. Saklatwalla, general superintendent, Vanadium Corporation of America, Bridgeville, Pa., in *Iron Age*, September 27, 1923, page 815.

In the above article the author tells how important it is to be able to control the changes taking place in the structure of the ingot during heat treatment and of the possible effect of electromagnetic treatment during solidification.

Reviews of Recent Patents

By

NELSON LITTEL, Patent Attorney
110 E. 42nd St., New York City

1,453,347. Electric Furnace. Alfred W. Gregg, Chicago, assignor to the Whiting Corporation, Harvey, Illinois, a corporation of Illinois.

This patent refers to an electric furnace having a metal receiving furnace box provided with doors through which material may be placed at one end, a pouring spout at the other end, means for leading electric current into the furnace to effect melting of material placed therein, trunnions extending from opposite sides of the furnace, intermediate of said spout and said doors, journal supports for the trunnions, an electric motor mechanism supported by a trunnion for rocking the furnace on the trunnions and expansion-permitting means on the support preventing rotation of the motor about the trunnion axis.

1,453,411. Process of Annealing Sheet Iron. James A. Smail, Youngstown, Ohio.

This relates to a method of annealing a pack of iron sheets which consists in bringing the pack up through an annealing temperature in an enclosed atmosphere, and then causing said pack to cool down rapidly while still closed off from the outside atmosphere.

1,454,464. Chrome-Iron Sheet or Article and Process of Making Same. Frederick M. Becket, New York and Charles E. McQuigg, Flushing, N. Y., assignors to the Electro Metallurgical Company, a corporation of West Virginia.

This patent refers to a process of making chrome-iron sheets or articles of relatively high ductility, comprising mechanically reducing the metal to sheet by rolling, drawing or equivalent steps; and subsequently rapidly cooling the heated sheet through the temperature range 600 degrees—400 degrees Cent.

1,453,928. Aluminum-Silicon Alloy and Method of Making It. Junius D. Edwards, Oakmont, Pa., assignor to the Aluminum Company of America, Pittsburgh, a corporation of Pennsylvania.

This refers to the art of making articles of an aluminum alloy containing a substantial amount of silicon, the improvement comprising incorporating in a finely divided state in the molten alloy, a metalloid of the fifth group of the periodic system of the elements, having an atomic weight greater than 100, and thereby favorably affecting the strength and ductility of the resulting alloy.

1,453,993. Metallurgical Refractory Material and Process of Producing the Same. Calvin Payton, Douglas, Arizona, assignor of fifty-five one hundredths to the Phelps Dodge Corporation, a corporation of New York.

This patent refers to a process of producing metallurgical refractory material which comprises blowing copper matte without the addition of silica and separating the resulting slag.

1,454,024. Reverberatory Smelting Furnace. Archie Noel Jette, Anaconda, Montana.

This invention relates to a reverberatory furnace comprising a furnace chamber and means for heating the same, a secondary chamber at the exit forming a metal bay, said secondary chamber being of sufficient size to permit the gases coming from the furnace to expand, and an exit flue from the secondary chamber having a damper therein.

1,454,025. Smelting Furnace. Archie Noel Jette, Anaconda, Montana.

This refers to a furnace in which there is a cast-iron plate having a tap-hole and a recess in the front thereof, a tap-hole block seated in the said recess and means for detachably securing the block in the recess.

1,453,397. Protection of Resistors of Electric Furnaces. George M. Little, Pittsburgh, assignor to the Westinghouse Electric & Manufacturing Company, a corporation of Pennsylvania.

This refers to an electric furnace, the combination with a housing enclosing a furnace chamber and having an opening near the bottom of said chamber for introducing material to be heated, and a carbonaceous resistor located near the top of said chamber, of a source of hydrocarbon vapor comprising an oil flame, means for conducting the products of combustion of said flame into said chamber near the bottom thereof and means for varying the amount of hydrocarbon vapor produced by said flame.

1,453,399. Means for Protecting Resistors in Electric Furnaces. George M. Little, Pittsburgh, assignor to the Westinghouse Electric & Manufacturing Company, a corporation of Pennsylvania.

This refers to a method for protecting resistors in an electro-resistance, the combination with a furnace chamber and a carbonaceous resistor therein, of means for introducing a hydro-carbonaceous fluid into said chamber under pressure, said means comprising a cam-and-spring-operated plunger pump.

1,454,214. Fused Salt Bath for Heating Steel in Hardening. Reginald Scott Dean, Cicero, Illinois, assignor to the Western Electric Company, Inc., New York City, a corporation of New York.

This relates to a method of maintaining a fused salt bath in a non-oxidizing condition for the heating of steel in hardening, which consists in adding a readily oxidizable material to the molten bath.

1,455,748. Electric Induction Furnace. Albert E. Greene, Seattle, Washington.

This patent relates to an electric induction furnace comprising a primary winding, an endless channel in refractory material to contain molten metal and form the secondary circuit of the induction furnace, an auxiliary channel leading down into said first named channel for pouring molten metal into said endless channel, and another auxiliary channel in refractory material leading upwardly from said endless channel at another point thereof for the exit of metal, whereby an increased head of metal may be maintained on the metal in the endless channel while heating the metal therein.

1,456,088. Heat-Treated Stable-Surface Alloy Steel. Percy A. E. Armstrong, Loudonville, N. Y.

This refers to an alloy steel of substantially high surface stability, having the ground mass fixed substantially solid solution by heat treatment, containing chromium about 3.0 per cent to 10.0 per cent, silicon about 0.5 per cent to 0.7 per cent, chromium and silicon together about 5.0 per cent to 13.0 per cent, carbon over about 0.05 per cent and under 1/10 of the chromium and silicon taken together, and the principal portion of the remainder iron.

1,456,107. Electric Resistance Furnace. Carl L. Ipsen, Schenectady, N. Y., assignor to the General Electric Company, a corporation of New York.

This relates to an electric resistance furnace comprising a furnace wall, flat metal strips mounted in said wall, the longer transverse axis of said strips extending vertically, refractory insulators mounted on said strips abutting said wall, and resistance heaters mounted on said insulators.

1,456,298. Combined Furnace and Crucible. William T. Carnes, Kansas City, Mo., assignor to the Carnes Artificial Limb Company, Kansas City, Mo.

This invention refers to a furnace comprising a furnace chamber, means to heat the same, an opening in each end of each chamber, means to support said chamber in a vertical position, a crucible adapted to be inserted into the upper end of said furnace chamber and extend downwardly therein, means to suspend said crucible therein and lower the same through the opening in the lower end of said furnace chamber, a nozzle on the lower end of said crucible, a valve to control the opening through said nozzle, and means to operate said valve.

1,456,788. Billet-Heating Furnace. Nicholas F. Egler, Chicago, Ill., assignor by mesne assignments to the Union Trust Company, trustee, Cleveland.

This relates to a recuperative furnace comprising an elongated

combustion chamber and pipes lying across said chamber through which air passes for preheating said air for the furnace.

1,456,837. Apparatus for Charging or Discharging Furnaces. Martin **Van Marle, Lower Gornal, England.**

This refers to an apparatus for feeding goods into or removing goods from furnaces, comprising an undercarriage, an upper traveling carriage movably mounted thereon, said upper carriage including a supporting element and an independent goods carrying element resting thereon, inclined blocks on one of said elements having each an inclined face and a substantially horizontal face, abutments on the other of said elements, means carried by said undercarriage for moving said upper traveling carriage as a whole with respect to the undercarriage and means carried by said upper traveling carriage for moving one of said elements with respect to the other of said elements irrespective of movement of the undercarriage, whereby said inclined blocks co-act with said abutments to alter the level of the goods carrying element.

1,456,890. Electric Resistance Furnace. George M. Little, Pitts**burgh, assignor to the Westinghouse Electric & Manufacturing** Com**pany, a corporation of Pennsylvania.**

This patent refers to an electric furnace comprising a metal container, a metal cover for said container, a metal base plate secured to and insulated from said container, means for attaching electric supply-circuit terminals to said container, granular resistor material surrounding said crucible, and means in said cover for compressing said resistor material in said container.

1,456,891. Electric Furnace Resistor. George M. Little, Pittsburgh, assignor to the Westinghouse Electric & Manufacturing Company, a **corporation of Pennsylvania.**

This invention relates to an electric-resistance furnace comprising a built-up resistor consisting of single flat carbonaceous plates of relatively large area of cross-section alternating consecutively with a plurality of flat carbonaceous plates of relatively small area of cross-section, the area of cross-section of the small plates being in accordance with the kilowatt input of the furnace.

1,456,893. Electric-Furnace Wall Construction. George M. Little, **Pittsburgh, assignor to the Westinghouse Electric & Manufacturing Company, a corporation of Pennsylvania.**

This relates to an electric furnace comprising a plurality of walls enclosing a furnace chamber, a resistor located in said chamber and supported at one end thereof by one of said walls, a plurality of electrodes operatively engaging said resistor to conduct current to and from said resistor, and means for reducing the current leakage between and from said electrodes said means comprising a plurality of spaced apart refractory members surrounding said electrodes intermediate their ends and having only a relatively small area of surface contact between adjacent plates.

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list communicate with the National office in order that the list may be as complete as possible.

Boston—Third Thursday.

Cleveland—Fourth Friday, Cleveland Engineering Society rooms, Hotel Winton; meeting at 8 p. m.

Hartford—Tuesday nearest 10th of month.

New Haven—Third Friday.

New York—Third Wednesday, assembly room, Merchants Association of New York, ninth floor, Woolworth building.

Philadelphia—Last Friday, Engineers' club.

Tri City—Third Thursday.

BOSTON CHAPTER

THE Boston chapter of the American Society for Steel Treating held their regular monthly meeting on Nov. 15, at Watertown Arsenal, Watertown, Mass. There were about 100 members and guests present at this meeting, the program for which consisted of a plant visitation, including the inspection of the forge shop, heat treating department and laboratories. A buffet luncheon was served at the cafeteria hall at 6:30 p.m.

Major Nickerson representing Colonel Dickson, extended a welcome to the members and their guests. Dr. F. C. Langenberg presented a very interesting and particularly well received article entitled "Influence of Temperature on the Charpy Impact Value of a Group of Steels of Varied Composition." There were present at this meeting Messrs. F. P. Gilligan, W. S. Bidle and W. H. Eisenman. Mr. Eisenman expressed his sincere appreciation for the opportunity of visiting the Boston chapter meeting and advised the chapter that the 1924 convention would be held in their city. Mr. Bidle gave a few remarks, while Mr. Gilligan gave a very interesting talk on "The Ordnance Specifications and Their Value to the Steel Treaters." Dr. Lester gave a final address on the subject of "X-Ray Examination of Steel." This was a very exceptional talk and very much appreciated, as evidenced by the applause following Dr. Lester's presentation.

CINCINNATI CHAPTER

The Cincinnati chapter of the American Society for Steel Treating held a joint meeting with the Engineers Club of Cincinnati on Thurs-

day, Nov. 15, at 8:00 p.m. The speaker of the evening, W. J. MacKenzie, metallurgist, Interstate Iron & Steel Company, Chicago who gave a very interesting paper entitled, "The Manufacture of Alloy Steel" which was illustrated with motion pictures. This paper proved to be of great interest and value, inasmuch as Mr. MacKenzie is an authority on this subject. Dinner was served at 6:30 p.m. in the rooms of the chamber of commerce.

CLEVELAND CHAPTER

The Cleveland chapter of the American Society for Steel Treating held their November meeting on the twenty-third of the month in the Cleveland Engineering Society's rooms, Hotel Winton, at 8:00 p.m. The speaker of the evening, D. M. Strickland, manager of the development department of the American Rolling Mill Company, Middletown, O., spoke on "The Relation of Protective Coatings to the Corrosion Problem." Mr. Strickland gave a very capable presentation and a lively discussion ensued. Dinner was served at 7:00 p.m. preceding the meeting.

HARTFORD CHAPTER

The Hartford chapter of the American Society for Steel Treating held their regular monthly meeting in the rooms of the Hartford Engineers club on Tuesday, Nov. 13. T. H. Wickenden, of the International Nickel Company, addressed the members, choosing for his subject, "Use of Alloy Steels in the Automotive Industry." This paper was illustrated with blue print examples of various automobile parts made from alloy steels. Mr. Wickenden explained the method of determining the type of steel to be used by computing the stress involved in the various parts. Lively discussion followed this presentation, dealing mainly with the relative ease of machining the various types of alloy steels. R. J. Allen, Rolls-Royce Company of America, Springfield, Mass., gave a very interesting brief, during the discussion, on the type of steels used in the construction of the Rolls-Royce automobile. The meeting was well attended and an enjoyable evening was spent by all. Dinner was served at Hotel Garde preceding the meeting at 6:30 p.m.

LEHIGH VALLEY CHAPTER

The Lehigh Valley chapter of the American Society for Steel Treating has offered a prize of $25.00 to be awarded this year to that student of Lehigh university who presents the best thesis on any phase of the heat treatment of iron or steel. While the prize is offered for this year only, it is possible that it may be made a continuous one

in the event that sufficient interest in the subject is developed by the students.

The theses submitted in this competition will be judged by a committee consisting of Professor Bradley Stoughton, Professor F. V. Larkin and A. P. Spooner, chairman of the Lehigh Valley chapter of the society, or some member of the chapter appointed by him.

The prize will be awarded even though only one thesis on the subject is submitted, providing that thesis is considered a worthy one by the committee. Naturally, the Lehigh Valley chapter would prefer that a considerable number of students enter the competition, which is open to any engineering student, since the subject is of keen interest to engineers in general, irrespective of their particular field of specialization.

MILWAUKEE CHAPTER

The third meeting of the Milwaukee chapter of the American Society for Steel Treating was held at Hotel Blatz on Nov. 12, dinner being served preceding the meeting. The speaker of the evening, Tinius Y. Olsen, of the Olsen Testing Machine Company, Philadelphia, presented a very worthy paper, on "Testing Machines," illustrated with lantern slides. This paper gave a description of equipment for making all kinds of physical, dynamic and static tests on steel and other metals and materials. Several advance features of Olsen machines were illustrated. It was very gratifying to the officers and members of the chapter to witness the large number in attendance at this meeting and it is hoped that with the excellent program that the chapter has laid out for the coming year, the future meetings will be as well represented.

NEW YORK CHAPTER

About 150 members and guests of the New York chapter met for a dinner and smoker at the Cafe Boulevard on Wednesday, Nov. 21, 1923. The proceedings may best be explained in the words of the invitations which were issued:

DINNER

All the steps in this "Preliminary Treatment" cannot be told at length, but will include everything from—*Quenching Solution en Tasse to Spherordized Filberts,* timed accurately at 6:30.

The supervisory staff consisted of George K. Burgess, at the pyrometer; Frank P. Gilligan, at the furnace; Robert M. Bird, tensile and hardness; Bill Eisenman, final inspection.

ACCESSORIES

"Bones" by Aluminum Die Castings Corporation.

Razor Hones by Carborundum Co.

Picture Frames by Doehler Die Castings Co., (no responsibility assumed, for pictures framed!)

Stainless Knives by Firth-Sterling Steel Co.

Chatter

W. R. Bennett, called "Pop" by hardened treaters at Hartford, explained "*Why She Broke*" or something else designed to be cheerful.

Impromptu remarks from the supervisory staff at the call of the chairman. (As it turned out, Bob Bird opined that a steel treater ought to know what be is talking about when he says "annealing," and Bill Eisenman explained, as only a Clevelander can, why Boston is better than New York for a convention city.)

Smoker

This constituted the "*Final Heat Treatment.*" It was done by Metal & Thermit Co. and checked up by New York Testing Laboratories. It was guaranteed to normalize even the worst segregated sample.

The New York chapter takes this occasion to thank the firms who

Photograph of the Dinner Meeting of the New York Chapter, Held November 21, in the Cafe-Boulevard.

generously donated the accessories—which alone were worth the price of admission—and the smokes.

Alex. Hart, the modest chairman of the entertainment committee, deserves much credit for making this affair a complete success.

YES, WE HAVE NO BANANAS.

Yes, we have no test for hardness,
We have no test for hardness to-day.
We have Brinell and Turner and Rockwell and Drill Test,
And all kinds of theory, and say
We have that old fashioned file test,
The blacksmith says that it's best,
But Yes, we have no test for hardness,
We have no test for hardness to-day.

NORTH WEST CHAPTER

The North West chapter of the American Society for Steel Treating held their regular monthly meeting on Nov. 13 at 8:00 p.m. in the Experimental Engineering building, of the University of Minnesota, Minn. T. Y. Olsen, of the Tinius Olsen Testing Machine Company of Philadelphia, addressed those in attendance on the subject of "Testing Machines and Their Uses." Mr. Olsen discussed the testing machines used in iron and steel practice, as well as the significance of the results that are obtained. The firm of which Mr. Olsen is a member is one of the pioneers in this particular field. His article was nontechnical and proved to be highly interesting.

PITTSBURGH CHAPTER

The regular monthly meeting of the Pittsburgh chapter of the American Society for Steel Treating was held on Nov. 13 in the Hawaiian room of the Wm. Penn hotel, at 8:00 p.m. Minutes of the previous meeting were read and approved and a report was given by Dr. C. M. Johnson, chairman of the Meetings and Papers committee of the chapter. Chairman Hoffman advised that local representatives were appointed in each locality to look after the interests of the chapter. Prof. H. Hower of Carnegie Institute of Technology gave a very interesting talk on "The Physical Basis of Pyrometry."

RHODE ISLAND CHAPTER

The Rhole Island chapter of the American Society for Steel Treating held their regular monthly meeting on Friday, Nov. 9 in the rooms of the Providence Engineering society at 8:00 p.m. The speaker of the evening, W. R. Bennett, practical steel treating engineer of Hartford, Conn., gave a practical talk on steel treating. This paper appealed especially to "the man at the fire" inasmuch as Mr. Bennett spoke on the methods which have gained for him success, giving reasons for adopting certain methods. This was a very capable presentation and proved to be very instructive.

ROCKFORD CHAPTER

On Friday, Nov. 16, the Rockford chapter of the American Society for Steel Treating held their regular monthly meeting at the Nelson hotel, preceded by the usual get together dinner served at 7:00 p.m. Those in attendance were addressed by T. Y. Olsen, of the Tinius Olsen Testing Machine Company, Philadelphia, on the subject of "Testing Machines." Mr. Olsen described equipment for making all kinds of tests on steel and other metals. His lecture was illustrated with lantern slides.

SCHENECTADY CHAPTER

Enrique Touceda addressed the members and guests of the Schen-

ectady chapter of the American Society for Steel Treating on Tuesday, Nov. 20 in the Civil Engineering building, Union College, choosing for his subject "Cast and Malleable Iron." Mr. Touceda, who is consulting engineer for the Eastern Iron association, is a nationally recognized authority on iron and he presented his paper in a very capable manner.

SOUTH BEND CHAPTER

The South Bend chapter of the American Society for Steel Treating held a meeting on Oct. 24 at the South Bend high school, jointly with the American Chemical society, the American Association of Engineers and the Mishawaka Engineering club. Prof. H. F. Moore, University of Illinois, delivered a most interesting talk on "Investigation of the Fatigue of Metals." In this paper was described the progress that has been made at the university and motion pictures were shown giving many interesting and instructive data on fatigue.

W. F. Newhouse, superintendent of the Saranac Machine Company, an active member of the chapter, gave a most interesting paper entitled, "The Relation Which Should Exist Between the Experienced Employe and the Apprentice." Due to the rather lengthy main address of the evening, discussion of Mr. Newhouse's paper was deferred until the next meeting of the chapter.

The November meeting of the chapter was held on the twenty-first of the month at the Studebaker Corporation dining room, Plant No. 2. The program for this meeting consisted of a six-reel film entitled "The Story of Steels," which had been obtained from the Bureau of Mines, United States Department of Interior. This film is a very interesting treatise on the various phases of steel manufacture from the raw materials to the finished products.

SPRINGFIELD CHAPTER

The Springfield chapter of the society held a meeting on Thursday evening, Nov. 22 at 8:00 p.m., in the Springfield Chamber of Commerce rooms. A. H. d'Arcambal, metallurgist, Pratt & Witney Company, Hartford, Conn., addressed the members and guests, choosing for his subject "Carbon Tool and High-Speed Steel Used in the Manufacture of Small Tools." This was illustrated with lantern slides and there were shown specimens of tools which had failed through faulty treatment or faulty material. This was a very capable presentation and of much interest to the practical heat treater and the tool room man.

SYRACUSE CHAPTER

On Oct. 26 the Syracuse chapter of the American Society for Steel Treating held a meeting at the Yates hotel and was addressed by Dr. C. M. Johnson, of the research department, Park Works, Crucible Steel

Company of America, on "Stainless Steel and Heat Resisting Alloys." This meeting was very well attended.

The chapter held their November meeting on the ninth at the Onondaga hotel at 8:00 p.m. The speaker of the evening was A. H. d'Arcambal, chief metallurgist, Pratt & Whitney Company, Hartford, Conn., who chose for his subject "High Speed Steel." Mr. d'Arcambal is an authority on this subject and very instructive discussion was brought forth following the presentation of the paper.

TRI-CITY CHAPTER

The Tri-City chapter of the American Society for Steel Treating held a joint meeting with the Tri-City branch of the American Society of Mechanical Engineers and the Clinton Engineering society at the Davenport chamber of commerce, on Oct. 25. At this meeting Prof. H. F. Moore of the University of Illinois presented a paper on "Fatigue of Metals" which showed the progress which had been made during the past year. Considerable discussion followed this presentation. This meeting was well attended.

WASHINGTON CHAPTER

The Washington chapter of the American Society for Steel Treating held a meeting on Nov. 2 at 8:00 p.m. in the auditorium of the New Interior Department building. There were present at this meeting Robert M. Bird, engineer of tests, Bethlehem Steel Company, who gave a short, informal illustrated talk covering his recent work with copper steels; T. D. Lynch, manager, M. and P. engineering department, Westinghouse Electric & Manufacturing Company, who spoke on heavy forging and W. H. Eisenman, national secretary, who covered briefly some of the recent accomplishments and the future plans of the society.

WORCESTER CHAPTER

The Worcester chapter of the American Society for Steel Treating held a joint meeting with the local sections of the American Society for Testing Materials and the American Society of Mechanical engineers, on Tuesday, Nov. 13. The program of the evening included addresses by Captain S. P. Crim on the Subject of "Government Plans for Industrial Mobilization;" Dr. F. C. Langenberg, metallurgist, Watertown Arsenal, Watertown, Mass., on "Influence of Temperature on Charpy Impact Tests;" and General T. C. Dickson, commandant of Watertown Arsenal, described the use of X-ray photographs in detecting flaws in steel castings. There were about 150 in attendance at this meeting. The chapter has elected the following new officers: G. C. McCormick, chairman; P. A. Porter, vice chairman; W. C. Searles, secretary treasurer, and members of the executive committee are: C. Daniels, E. C. Meyer, and L. P. Greenman.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ANDERSON, M. M. (M-9), 336 St. Asaph Street, Christ Church, N. Z.
BURGESS, C. M. (M-11), Burgess Norton Manufacturing Company, Geneva, Ill.
CARLSON, E. H. (A-11), Leeds & Northrup Company, Philadelphia.
COTTER, WM. J. (M-11), 118 Barker Street, Hartford, Conn.
DAHMS, H. G. (M-11), 707 Hamilton Street, Pottstown, Pa.
DAPOGNY, M. (M-11), Chicago Foundry Company, Chicago.
DAPOGNY, P. (J-11), Chicago Foundry Company, Chicago.
DOESCHER, C. (M-11), 1161 Bank Street, Waterbury, Conn.
DYER, I. (M-11), 332 Richie Avenue, West Collingwood, N. J.
EDEMA, B. J. (M-10), P. O. Box 496, East Liberty Station, Pittsburgh.
GROFF, J. S. (M-11), Naval Torpedo Station, Newport, R. I.
GROSS, J. B. (M-10), 223 South Highland Avenue, Pittsburgh.
HANDYSIDE, G. (M-11), 27 Georgetown Street, Buffalo, N. Y.
HARR, M. B. (A-10), Westinghouse Electric & Manufacturing Company, Detroit.
KIRCHER, G. (J-11), 1083 27th Street, Milwaukee, Wis.
LAMBERT, E. (M-11), 264 Union Street, Hackensack, N. J.
MCGONIGAL, W. S. (A-11), Philadelphia Electric Company, Philadelphia.
MUSSER, R. H. (M-11), Union Electric Steel Corporation, Carnegie, Pa.
NEHRER, G. J. (M-11), 890 Walden Avenue, Buffalo, N. Y.
PRICE, F. C. (M-9), W. H. Price & Sons, Christ Church, N. Z.
RANSOM, F. X. (A-11), 340 Leader News Building, Cleveland.
ROSEBAUGH, H. M. (M-11), 13821 Shaw Avenue, Cleveland.
ROWE, F. D. (M-11), 19 Grande Avenue, Stratford, Manchester, England.
RUSSELL, C. E. (A-11), Philadelphia Electric Company, Philadelphia.
SAWYER, L. E. (M-11), Babcock Wilcox Company, Beaver Falls, Pa.
SCHAEFER, J. G. (M-12), 530 Park Street, Milwaukee, Wis.
SWIFT, P. (M-10), Stanley Works, New Britain, Conn.
STEWART, W. J. (M-10), 400 Edgemont Street, Pittsburgh.
WEBER, L. J. (M-11), School of Mines, University of Minnesota, Minneapolis, Minn.
WRIGHT, F. L. (M-11), 7012 Cresheim Road, Germantown, Pa.

MAIL RETURNED

BLACKBURN, C. J. 52 Garfield Avenue, Detroit.
BOWERS, W. 1082 East 141st Street, Collinwood, Ohio.
MILLER, A. P. P. O. Box 1124, Pittsburgh.
THOMAS, C. P. 910 Pine Street, Lansing, Mich.
WOODWARD, E. L. Railway Mechanical Engineer, 608 South Michigan Avenue, Chicago.

Items of Interest

A REAL HEROINE, THE TUBERCULOSIS PUBLIC HEALTH NURSE

By Elizabeth Cole

PROBABLY no movement in the bettering of health conditions has grown more rapidly than the nursing movement. When the fiftieth anniversary of the inauguration of trained nursing was celebrated last May, it came as a surprise to many that this professional work was so recent. Yet, in 1880 there were only fourteen training schools for nurses as compared with today's number which is about 1700, with approximately 175,000 trained nurses in the field.

One of the chief factors in the nursing movement is the public health or visiting nurse. She is now a recognized part of every health program, and it is interesting to realize that there are practically 12,000 of these nurses who are bringing better health and education into our homes. Of this number a large proportion are specialized tuberculosis nurses.

There are certain recognized requirements and duties for the public health nurse, in some ways quite different from that of the private nurse. She must be a graduate from an accredited training school; she does not distribute material relief; she in no way interferes with the religious views of her patients. She observes carefully professional etiquette with her physician, in that she never diagnoses cases, prescribes medicine, or recommends hospitals. She keeps accurate records. Her work necessarily demands a daily schedule of hours for, unlike the private nurse, her duties are arranged by the year and do not allow for occasional respites. She seldom cares for acute illnesses that demand her remaining over night to do bedside nursing. She is in most cases a health visitor who instructs the family in the care and prevention of sickness. She becomes the friend, the teacher of health and her opportunities for raising health standards in the community are great.

The patients who call upon the services of the public health nurse may be divided into four groups: Those who can make no payment; those who can make partial payment; those who can pay cost price, but who are not able to afford a private nurse; and those who, able to afford anything, prefer the public health nurse for convenience. The financing of public health nursing, therefore, is a great problem. Sometimes the state, county or municipal governments pay her salary. The owner of a business concern oftentimes assumes this responsibility. Philanthropic organizations, women's clubs, men's clubs, local health associations, or popular contributions by members of her community, in many cases pay for part or all of her services. It is readily seen, however, that the standardized financing of such a necessary element in the community's progress of health must be placed upon a firmer footing.

Her part in the tuberculosis movement has been and is most important. The first nation-wide effort to stamp out this disease was first made in 1904 with the organization of the National Association for the Study and Prevention of Tuberculosis, now known as the National Tuberculosis Association.

To the success of this campaign the tuberculosis public health nurse has contributed no small share. Hard work, difficult situations to meet, as well as the constant contact with a highly infectious sickness means that this nurse must be courageous—a real heroine. To her, much of the success of the work is due.

Bedridden tuberculosis patients had been cared for by general visiting nurses for several years before 1899 when two women medical students, under the late Sir William Osler's direction, went to the homes of several patients who had been coming to the Johns Hopkins Hospital dispensary in Baltimore. Here they instructed them regarding diet, fresh air, disposal of sputum. This follow-up work, undertaken for the purpose of education, and really social in its aspect, resulted in co-operation with a charity organization for relief, and with the board of health in regard to sanitary conditions. After one year of work of this nature, nurses systematically undertook specialized tuberculosis public health nursing and the organized movement was begun with New York, Baltimore, Cleveland and Boston in the lead.

The tuberculosis nurse's work is far from easy. She is not only a nurse but also a health teacher and her responsibilities include, briefly: The prevention of the spread of infection; the discovery of new cases; the care, by instruction of nursing service, of patients in the home; co-operation with other agencies; her duties at clinics and dispensaries, as well as seeing that patients realize the need of going there for periodic physical examination. She also keeps records and statistics in order to contribute her part toward showing whether the community is growing better, standing still, or becoming worse in its number of tuberculosis cases and deaths.

The nature of tuberculosis is such that the tuebrculosis nurse must have much patience and a vivid spirit of hopefulness. Inasmuch as the disease is so highly infectious her problem deals not only with the individual, but also with the community. She must work to prevent the spread of infection. There is nothing more pathetic than a hopeless case of tuberculosis. Struggling for life and suffering intensely, this patient is an ever-threatening source of infection, and the tuberculosis nurse cannot allow herself, through sympathy, to devote more time to him than to ones who are ill, but who will probably recover, or to those who are well and must not be infected. An active case generally receives better care and is better off in a sanitorium or hospital than in the single tenement bedroom. It is not easy, however, to separate him from his loved ones, and again sympathy must give way to tactful insistence on what is best in the end both for the individual and for the community.

What a vast amount of advice will be followed in the home if the nurse has won her way into the hearts of the mother and children! Her word can be law. She helps plan the meals,—the food, the proper kind and in sufficient amount, is a most necessary element in both the prevention and cure of tuberculosis. The pots and pans shine for her approval. No longer is dust lurking in the corners or brushed under the rug. The tuberculosis patient has his sputum cup, eats from his own dishes, has plenty of fresh air and sunshine. Every member of the family knows the rules of the health game and gets his sufficient number of hours of sleep and exercise. Even the tiny baby has a good start on the road of life. She takes them to the free clinic where an expert physician keeps watch over their physical condition. She

(*Continued on Page 36 Advertising Section*)

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STAINLESS STEEL

—*Resists Corrosive Action*

Diameter 12 in.

A Die was required for stamping the trade name "Carey-ized" in salt-licks—very hard, dense blocks of salt, made by compressing salt crystals under hydraulic pressure.

This meant that the die must withstand not only the tremendous stamping pressure necessitated, but also the corrosive action of the salt.

A bronze die was tried, and failed. It resisted corrosion, but was unable to stand up under the pressure.

A die made of Bethlehem Stainless Steel proved suitable in every way. Bethlehem Stainless Steel is the one material that can readily be hardened to withstand great pressures and that also resists the action of the more common corrosive agents.

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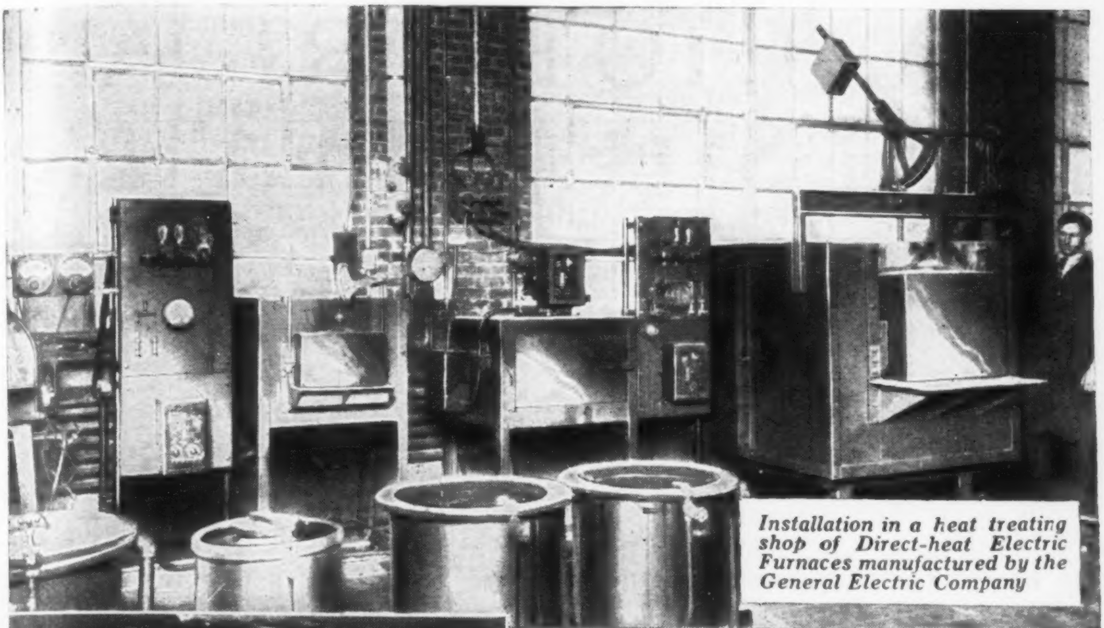
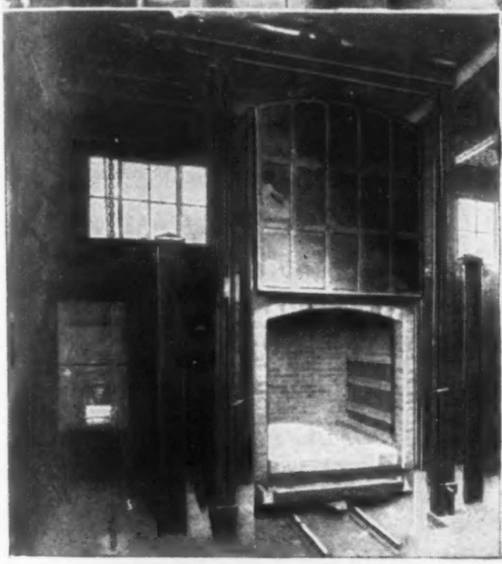


Installation in a heat treating shop of Direct-heat Electric Furnaces manufactured by the General Electric Company



Heat treating furnace equipped with G-E Direct-heat Units and Automatic Temperature Control

G-E Industrial Heating Specialists will gladly help you work out a better heat treating furnace plan—through the proper application of electric heat.

Electric Heat Treating With G-E Equipment

The General Electric Company manufactures Direct-heat Electric Furnaces, complete in standard sizes, and Direct-heat Units to equip electric furnaces of larger sizes—meeting the requirements of heat treating processes of any nature in industry today.

The heating unit, located in the furnace chamber, radiates its heat directly to the charge. This produces rapid heating, and permits of quick changes in temperature when desired—and insures uniform temperature throughout the chamber.

This type of heating unit responds more quickly to automatic control, and operates at lower temperature for any given temperature in the furnace chamber, than any other type. It means long life to the furnace.

Quick, clean, accurately controlled heat that speeds production and reduces spoilage is essential to every heat treating process. You secure these advantages with G-E Direct-heat Units and Automatic Temperature Control.

General Electric Company
Schenectady, N. Y.
Sales Offices in all large cities

GENERAL ELECTRIC

HEART TO HEART TALK WITH STEEL TREATERS

By the President of E. F. HOUGHTON & CO.

"Conceit may puff a man up, but never prop him up."

—Ruskin.

THERE are a few readers of this journal who criticise me severely for the use of the first person singular in these Talks. In their opinion, I should resort to the usual editorial camouflage "we," a custom which to me always seems void of frankness and courage.

Just why a man who addresses the public in writing should use "we" when he is solely responsible for his remarks, and use "I" when he addresses the public orally, I do not understand. I am responsible for these Talks and it is not fair to appear to include any others in that responsibility.

The object of these Talks is to take the readers into my confidence and thus obtain their confidence. I fail to see how that confidence can be best created by assuming grammar which literally interpreted, leads the reader to believe that two or more persons are the authors of these Talks, when in reality there is only one author.

I am accused of being conceited because I use "I." Well I am conceited and as WE pay valuable money for this space to enable me to tell facts to the readers, I have no desire to conceal the fact. There is no necessity for me acknowledging that I am conceited, because the fact is well-known. Every successful man is conceited, because success breeds conceit and there can be no success without conceit. The successful man who obtains a reputation for extreme modesty, is merely the man who has learned how to conceal his conceit.

If my memory serves me correctly, "Teddy" was accused of being conceited and criticised for using the upper case "I." So I am at least in good company.

But I am not a braggart or a boaster of my own accomplishments and when I refer to the accomplishments of E. F. Houghton & Co., I have no consciousness of boasting of my own achievements, because the success of E. F. Houghton & Co. is due to no one man and as the Company has never in the past even paused in its career of progress because of the loss of any single one of its human units, it will neither stop nor pause in the future.

If the members of the Houghton Family were asked to vote as to who was the most valuable man in the organization today, I am very certain that the vote would be well-divided among at least a half dozen. When I go, the plant will shut down for a half day to permit the members of the Houghton Family to pay their last respects to me; the next meeting of the Board will elect my successor; there will be a slight readjustment of duties and the business will continue steadily on.

When I refer to the accomplishments of our Company, I always do so with a feeling that I am complimenting my associates, rather than myself.

The success of E. F. Houghton & Co. is organizational, rather than individual.

In acknowledging my conceit, I make no pretense in believing that conceit is a virtue. Nature has provided ways and means of handicapping men who succeed. Wealth itself is a handicap and has many disadvantages. Rich men's sons are at a disadvantage rather than at an advantage because of the wealth of their family. But conceit is not fatal, so long as one knows one is afflicted with the disease.

But notwithstanding the adverse criticisms, I receive many more complimentary letters, which of course encourage me in the creation of further copy, for it would be impossible for me to create copy of this sort, if I did not possess self-confidence.

Self-confidence is not necessarily conceit.

Self-confidence is more often due to courage, which is in turn created by knowledge of the fact that one has nothing to fear.

The business man who resorts to unfair business practices becomes a coward, because of the very knowledge of those practices and immediately seeks shelter under the old axiom, "Don't put anything in writing." But the honest man need never fear to write the plain truth.

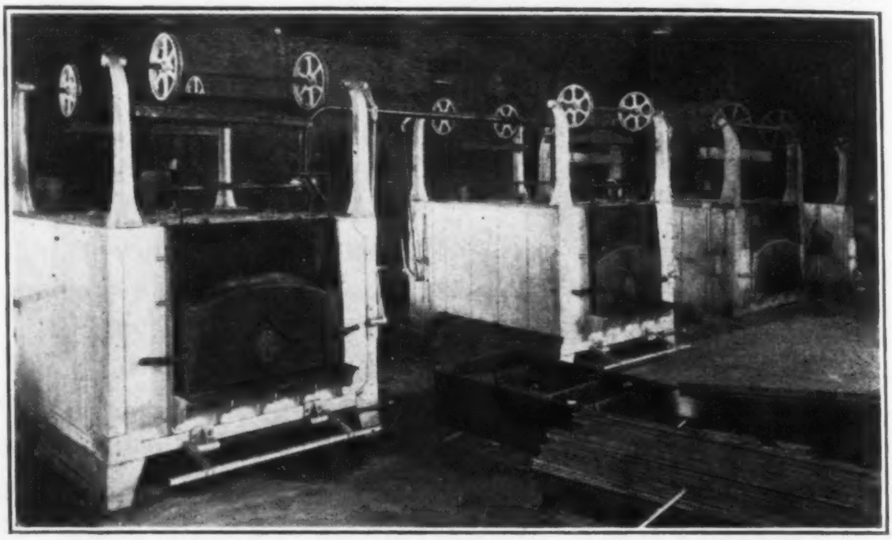
The noun "conceit" has 11 different definitions in the "Century Dictionary," only one of which refers to "an exaggerated estimate of one's own mental ability or importance or value of what one has done." All of the others refer to conceit as being imagination of a more or less creditable nature and the definition which I quote, is only fifth in importance and usage. And as imagination is the most important qualification in an executive, perhaps after all conceit is an essential qualification to success, for the first definition is, "That which is conceived, imagined or formed in the mind; conceptional idea; thought; image."

So again I plead guilty to the charge of being conceited.

Yours fraternally,

CHAS. E. CARPENTER,

President of E. F. Houghton & Co.



Tools, after test

"A" Heat-treated by eye

"B" Heat-treated by Brown Pyrometers

Eye vs Browns

Results of Government Heat-treating test

THIS Government test was conducted under ideal conditions. The heat-treaters competing against the Brown Pyrometer were picked men.

Tools tested: Pneumatic Cape Chisels 7/8″ octagon, 8″ long. Twelve chisels were treated by eye and twelve by Brown Pyrometer.

Test: Cutting 5/16″ Key-way in old locomotive axle.

Method: Heat-treated in lead pot to 1440°F. Quenched in 10% brine at 60°F. and drawn to 550°F. in lead alloy. Temper checked in oil. Shank of chisel reheated to 1350°F. to relieve forging strains.

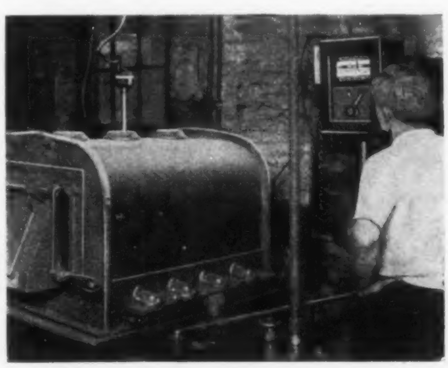
Tools "A" heat-treated by Eye:

Only one tool out of twelve finished the test.

Tools "B" heat-treated by Brown Pyrometer:

All finished with shank mashed ½″ and flat cutting end showing *No Wear.*

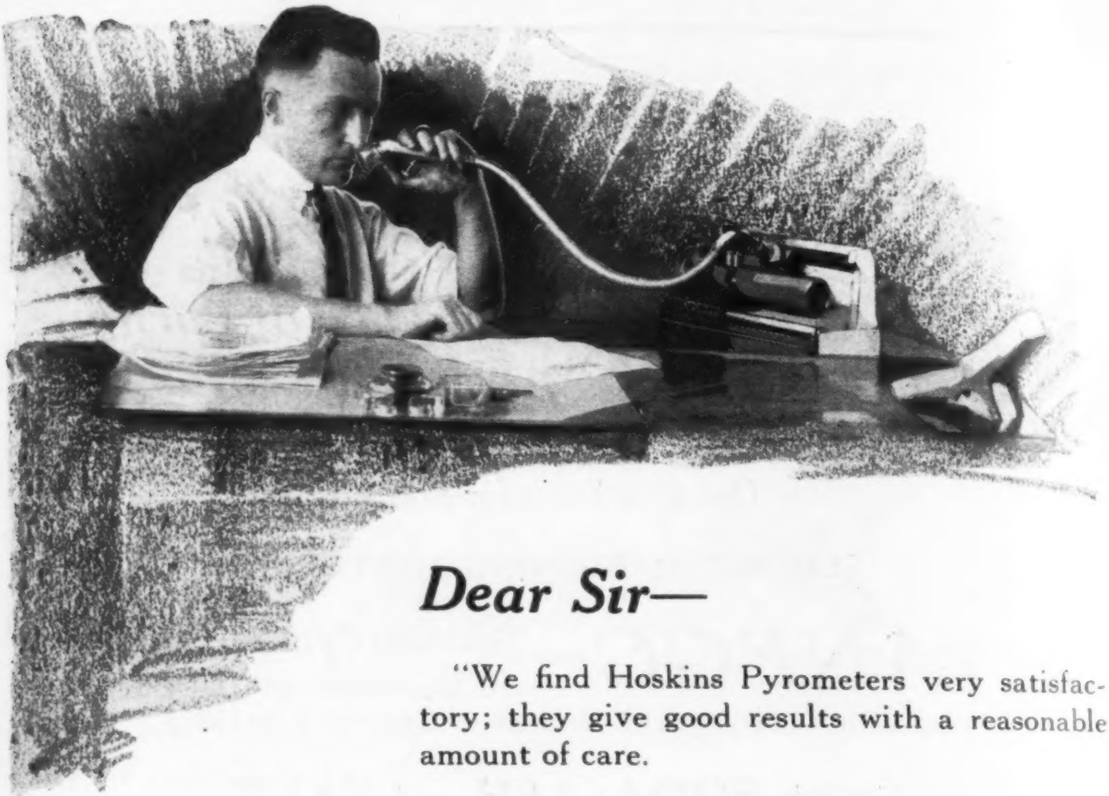
Our folder 23-9 gives in detail four other Government tests of Eye vs Browns. Write now for a copy to The Brown Instrument Company 4502 Wayne Ave., Philadelphia, Pa. or district offices at New York, Boston, Pittsburgh, Cleveland, Columbus, Birmingham, Detroit, Chicago, St. Louis, Denver, San Francisco, Los Angeles, or Montreal.



Furnace equipped with Brown Pyrometer
Thermocouple installed thru crown.

Brown Pyrometers

Most used in the world



Dear Sir—

"We find Hoskins Pyrometers very satisfactory; they give good results with a reasonable amount of care.

The thermocouples are being used at the high temperatures necessary to harden high speed steel. It is the only base metal couple which we have found that will successfully stand up in these high heats.

We find it a big saving to be able to salvage our old couples and to make new ones by simply cutting them off and welding with an acetylene torch."

Yours very truly,

NATIONAL TWIST DRILL & TOOL CO.

J. H. McCadie (Signed)

Metallurgist.

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HEAT RESISTANT ALLOYS
ELECTRIC FURNACES

THE METAL THAT MADE ELECTRIC HEAT POSSIBLE
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ELECTRICAL RESISTOR ALLOYS
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HENRY MARION HOWE MEDALIST

EMANUEL J. JANITZKY 1922

RULES GOVERNING THE AWARD OF THE HENRY MARION HOWE MEDAL

The Board of Directors of the American Society for Steel Treating has established a fund to be known as the Henry Marion Howe Medal Fund, the proceeds of which shall be used annually to award a gold medal to be known as the Henry Marion Howe Medal. The award will be made as follows:

(1) The medal will be awarded to the author of the paper which shall be judged to be of the highest merit. All papers in order to be considered must be published originally in the TRANSACTIONS of the Society during the twelve months ending August 1st of the year in which the medal is awarded.

(2) The competition for the Henry Marion Howe Medal shall be open to all.

(3) The award shall be made by the Board of Directors.

(4) The award may be withheld at the discretion of the Board of Directors.

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R. T. BAYLESS, EDITOR

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EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions Fee must accompany copy.

Important Notice

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS WANTED

METALLURGIST—EXECUTIVE. Twenty years experience as chemist, metallographist and executive in iron and steel foundry. Also heat treating and annealing castings and forgings, electric converter and open-hearth, rolled material (billets, skelp and tinplate). Connection desired where experience will be valuable and opportunity to demonstrate ability. References furnished if desired. Address 11-5.

TOOL HARDENER. Experienced tool hardener wishes position with reliable firm. Can give best of references. Any locality will be considered. Address 11-10.

SALES ENGINEER, Metallurgical engineer, superintendent, assistant superintendent or any position requiring a man with a technical training. Technical graduate. Married. Age 35 years. Connected with reliable firm for a number of years in the capacity of metallurgical engineer in conjunction with mill operation and sales. Address 11-20.

COMBUSTION ENGINEER Specialty heat treatment furnaces. Has after his graduation 13 years experience in study and development of industrial furnaces. Constructed 200 experimental furnaces of his own design for gas, oil, powdered coal and anthracite culm. For years connected with leading concerns in furnace specialty. Owns patents, publications, has good references. Wishes full or part time employment with some big concern. Undertakes investigation, reporting and consultation work in fuel economy or furnace efficiency line. Write O. Lellep, 111 West Seventy-Sixth Street, New York City.

TOOL HARDENER has had 12 years experience with carbon, high speed and alloy steels, covering all phases of heat treating. Wishes position with firm where individual can show ability. American. Married. Age 35. Can give first class references. Eastern location preferred, but will go anywhere. Address 12-10.

POSITIONS OPEN

WANTED: METALLURGICAL ASSISTANT—experienced in the analysis of steels and other materials of machine construction, and having practical knowledge of heat treatment, testing of materials and machine shop practice. For the capable man, ambitious and willing to work his way up, this is an exceptional chance to connect with a reputable Chicago concern where both opportunity and appreciation are presented. Give complete record of working experience, education and other essential details in first letter. Address 9-5.

POSITIONS OPEN

SALESMAN WANTED to handle a line of industrial furnaces, hardening room equipment, metallurgical, chemical and high temperature engineering equipment and service, by a well established and reputable engineering company. Chicago territory. Address SERVICE, 708 West Madison Street, Chicago.

WANTED THOROUGHLY EXPERIENCED HARDENER FOREMAN. Must have executive experience and complete knowledge of heat treatment of high speed, carbon and alloy steels as well as carbonizing. Hardening plant is constructed with all modern appliances. State age, experience and salary expected. Address 12-5.

SALESMAN—Single young man with one to two years' selling experience, to call on industrial trade. Fundamental electrical knowledge, and some mechanical and metallurgical knowledge needed. Engineering schooling preferred but not essential. A live energetic young man, willing to travel and willing to put in some extra effort at improving and preparing himself for advancement. Long established mechanical and electrical equipment of specialty nature and leading quality. Moderate salary and expenses to start and short training period. Some service on equipment required and rendered by salesman. State selling experience fully, age, schooling, general experience and references of selling ability and general character and salary. Address 11-30.

ASSISTANT SUPERINTENDENT OF FORGE LABORATORY in large university in middle west. Salary $2200.00. Candidate should be technical graduate with practical experience in the heat treatment of steel. Excellent opportunity for young man who wishes to enter the teaching profession and assist in the development of a course of instruction in heat treatment and in the conduct of research work. Address 11-25.

RESEARCH METALLURGIST AND METALLOGRAPHIST wanted by a large corporation. Sound fundamental training essential, few years additional practical experience in research or operations desirable but not necessary. Salary according to qualifications. Address 8-10.

WANTED: Fifty copies of Sauveur's Metallography and Heat Treatment of Iron and Steel needed at once. Prices will be paid for clean copies as follows:

1920 Edition—$7.00 per copy.
1918 Edition—$6.50 per copy.
1916 Edition—$6.00 per copy.

Send books by pre-paid parcel post to H. M. Boylston, c-o Case School of Applied Science, Cleveland, Ohio, and receive remittance by return mail.

it is who is responsible for catching the disease in time for early treatment. She it is who keeps up the cheerful spirits of the family. And she it is whom they all love and whose visits are greeted with joy.

Although here is a continual fight against a subtle, cruel enemy, there is no form of nursing in which the soul-satisfaction may be so great. Anything that is hard, and this is harder than any other form of public health nursing, with the element of education added, is only attempted by brave, unselfish types of persons. Undaunted by her problems, the tuberculosis public health nurse is really a heroine. She may go for days and feel that

Facsimile of National Tuberculosis Association Christmas Seal

her reward will never come—certainly not this side of heaven. Then suddenly a mother's grateful look, for her clean, metamorphosed home, a child's almost miraculous recovery, because the disease was caught in time,—some little incident like this, and she will know that her efforts are well repaid. This is indeed soul-satisfaction.

The tuberculosis public health nurse is so necessary, her work so important in the stamping out of tuberculosis in this country, that several tuberculosis training schools have been established in the last few years. A large proportion of nurses on general staffs, moreover, are carrying on specialized tuberculosis work. Yet, many communities have not sufficient funds to employ this special nurse. Christmas seal sale funds are used liberally to demonstrate their need in cities and counties. It is hoped that the Sixteenth annual Christmas seal sale in December will make it possible to give to more communities the benefit and comfort of better health that is contributed by the tuberculosis public health nurse.

Seals may be obtained by addressing the National Tuberculosis Association, 370 Seventh Avenue, New York City.

The Calorizing Company, Pittsburgh, announce the appointment of Mr. Roy Muir Ellis as New England sales manager with headquarters in Boston.

Mr. Ellis is a member of the American Society for Mechanical Engineers and was for seven years connected with the Brown & Sharp Mfg., Providence, R. I., in various executive capacities. During the war he was general manager of the A. H. Fox Gun Company in charge of their various plants engaged in the production of small arms for the United States and British governments. Subsequent to this connection, Mr. Ellis was engaged in financing, reorganization and management work as industrial engineer for the Industrial Company, Boston and for the last year or two in sales promotion work. He thus brings to his new work a wide experience in industrial matters and

a practical knowledge of heat applications in manufacturing that should prove useful to the New England manufacturers with whom he will have contact in discussing applications of Calco Recuperators, Calorizing and Calite.

It has been announced that the Atlas Steel Corp. will concentrate its manufacturing activities at its Dunkirk, N. Y., plant and dismantling its Charleroi, Pa., plant, transferring the equipment to Dunkirk. The Charleroi plant was purchased from the Universal Steel Co., Bridgeville, Pa., by the Electric Alloy Steel Co., a Youngstown, O., organization, headed by Louis J. Campbell, son of James A. Campbell, president Youngstown Sheet & Tube Co. About a year ago this company and the Atlas Crucible Steel Co., Dunkirk, were merged under the name of the Atlas Steel Corp. The Charleroi plant has been idle much of the time since the first of this year.

At the recent annual meeting of the Colonial Steel Co., held in Pittsburgh, a number of changes were made in the organization of the company. Charles M. Brown was elected president, Herbert C. Poole, who has been in charge of the New York office of the company for the past 13 years, was appointed general works manager, and Jacob Trautman Jr., who has been assistant sales manager, was appointed general sales manager.

In co-operation with the United States bureau of mines, the Laclede-Christy Clay Products Co., St. Louis, has developed a motion picture entitled "The Story of Fire Clay Refractories," using the plants and mines of the company as a background. According to an official of the department of the interior, the film covers one of the most instructive subjects that has ever been introduced under the direction of the bureau of mines and in point of photography and continuity is one of the best industrial films thus far developed.

Richard B. Sheridan, formerly in charge of the metallurgical laboratories at the Brooklyn, N. Y. works of J. H. Williams & Co., has joined the metallurgical staff of the same company at the Buffalo, N. Y., works.

The Adams & Durkee Steel Co., Inc., has been organized by W. E. Adams and W. B. Durkee to conduct a steel merchandising business, with office and warehouse at 287 Atlantic avenue, Boston.

Mr. Adams was associated with Edgar T. Wards Sons Company at Boston for the past twenty-two years; the last six years as a director of the company and sales manager of the New England branch.

Mr. Durkee has been connected with the steel business in Boston for the past fifteen years, the last six of which he has conducted a business under his own name, in Boston, handling direct mill business.

The company took over, on November 1, the business and warehouse of the Balfour Steel Company in Boston. The stock of tool steels, now carried by the Balfour Steel Company, will be very considerably increased and additional lines added, making a very complete stock of tool steels, cold finished steels, and specialties.

The Celtic Products Company of Chicago have recently instituted a novel method of distributing engineering data on their heat insulation products. For the convenience of engineers who may use that form of engineering data, they have reproduced many of their blueprints and charts in Lefax size sheets, punched and ready for insertion in standard Lefax loose-leaf binders.

These include charts showing comparative conductivities of Sil-O-Cel brick, red brick and refractories, as well as heat losses through various wall constructions, insulated and uninsulated and drawings showing methods of insulating such equipment as boilers, furnaces, ovens, brick, lime and cement kilns; gas equipment; glass equipment; oil stills, etc.

These "Lefax" size sheets are not intended to replace their regular literature and standard size blueprints but the number of requests received for this form indicates their popularity for ready reference purposes. Copies of these will be gladly sent to engineers on request.

Mr. T. Holland Nelson formerly steel works manager with Henry Disston & Sons, Inc., and finally in charge of their metallurgical research, is resigning this position to take charge of the works at Titusville of the Cyclops Steel Co.

Mr. Nelson is a native of Sheffield, England, was educated at the Sheffield university and was for several years employed by Messrs. Thos. Firth & Sons, Ltd., of Sheffield, finally becoming assistant to Harry Brearley the eminent British metallurgist, and inventor of "stainless steel." Mr. Nelson came to the United States in 1911 and joined the Simonds Manufacturing Co., later transferring to Messrs. Henry Disston & Sons. He returned to England and enlisted in the British army at the outset of war but was detailed to the manufacture of munitions. He was connected with the firm of Peter Stubs, Ltd., one of the oldest tool steel houses in England, and left that company as managing director in 1920 to return to the United States.

Mr. Nelson's whole life work has been spent in the manufacture of high grade tool steels and he possesses an extremely wide experience in this direction. He is an active member of the following societies: The American Iron and Steel institute, the British Iron and Steel institute, the American Society of Steel Treating and the Sheffield Metallurgical society. He has delivered a series of interesting lectures on high grade steels since his return to this country.

W. A. Jones Foundry & Machine Company, Chicago, have recently published two new catalogs and will mail copies free to interested parties on request. They are Catalog No. 27—Pulleys, and Catalog No. L-28—Friction Clutches. Catalog No. 27 gives new and valuable information on cast iron pulleys, including weights, illustrations and extra lists for special types, also describes and illustrates "Lemley" Ball Bearing Loose Pulleys, Ring Oiling Loose Pulleys as well as Steel, Wood and Paper Pulleys. Catalog No. L-28, gives valuable data on "Lemley" Friction Clutches. Sleeve Clutches, cut-off couplings, clutch pulleys, ball bearing clutch pulleys and gas engine clutch pulleys are also described giving price lists, dimensions, illustrations, horsepower ratings, etc.

(Continued on page 40)

Correct Metallographic Polishing

4570

Blurred and confused outlines of micro-structure and the reappearance of scratches after etching, are due to the excessive flow of metal when rouge, tripoli or other jeweler's powders are used for polishing.

S. M. Co. Levigated Alumina will correct this.

S. M. Co. Levigated Alumina

Specially prepared in our own laboratory for metallographic polishing.

No. 1 For the rapid polishing of steel and all hard metals. 1 oz. makes 50 ozs. polishing solution. **Per oz. $1.00.**

No. 2 For polishing medium hard metals, especially cast iron, bronze, brass, nickel and copper alloys. 1 oz. makes 100 ozs. polishing solution. **Per oz. $1.40.**

No. 3 For polishing soft metals also for specimens to be examined under the highest magnification. 1 oz. makes 150 ozs. polishing solution. **Per oz. $1.80.**

No. 4570 Polishing Machine

is adapted for the use of Alumina; has 6" hard rubber polishing head to which the polishing cloths are attached; contains a universal motor for 110 volt current. Complete, $115.00.

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"Everything for the Laboratory"

PITTSBURGH, PA.

Arthur G. Henry, special representative of the Vanadium-Alloys Steel Co., has resigned to become sales engineer with the Perfection Tool Hardening Co., 1229 South State street, Chicago, to take effect Dec. 1.

G. Bluemel has connected with Tate-Jones & Co., Inc., furnace engineers and builders, and will manage the New York sales district covering New York, New Jersey and New England with headquarters at 50 Church street, New York.

Mr. Bluemel is an experienced furnace engineer and was previously connected with the Ferguson Furnace Co. for eight years as chief engineer and vice president. Mr. Bluemel's experience will enable him to readily handle electric or fuel-fired furnace and fuel-engineering requirements as specialized in by Tate-Jones & Co., Inc.

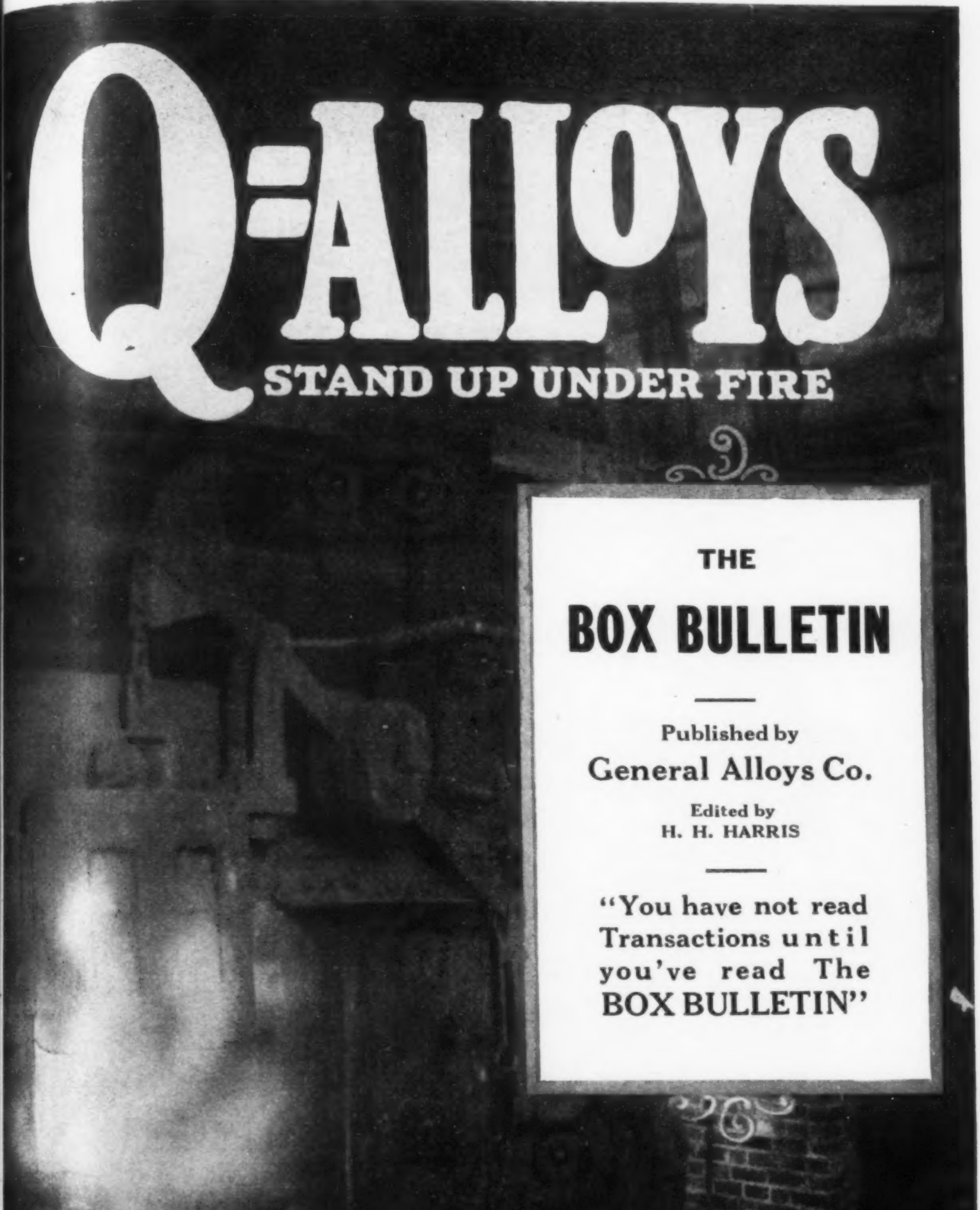
R. G. Hall has opened an office as metallurgical and chemical engineer, at 835 Hyde Street, San Francisco, California.

The United States Civil Service commission announces the following open competitive examination for the position of Junior Metallurgist.

The examination will be held throughout the country on January 9, 1924. It is to fill a vacancy in the Bureau of Mines, Department of the Interior, for duty at Reno, Nev., and vacancies in position requiring similar qualifications at entrance salaries ranging from $1500 to $2000 a year, plus the increase of $20 a month granted by Congress.

Applicants must have been graduated with a bachelor's degree from a college of recognized standing with major work in metallurgy. Special credit will be given for practical experience in metallurgical work or for graduate work in metallurgy in an institution of recognized standing. For the present vacancy it is desired to obtain eligibles who have had practical experience in research work in gold and silver metallurgy.

Competitors will be rated on general chemistry, elementary physics, metallurgy, and education, training, and experience. Full information and application blanks may be obtained from the United States Civil Service Commission, Washington, D. C., or the secretary of the board of United States civil service examiners at the post office or customhouse in any city.


Q-ALLOYS
STAND UP UNDER FIRE
THE
BOX BULLETIN
Published by
General Alloys Co.
Edited by
H. H. HARRIS
"You have not read Transactions until you've read The BOX BULLETIN"
GENERAL ALLOYS COMPANY

BOX BULLETIN SUPPLEMENT

Hear Ye,

That in the coming year ye may
Find peace of mind at work,
and e'en at play.

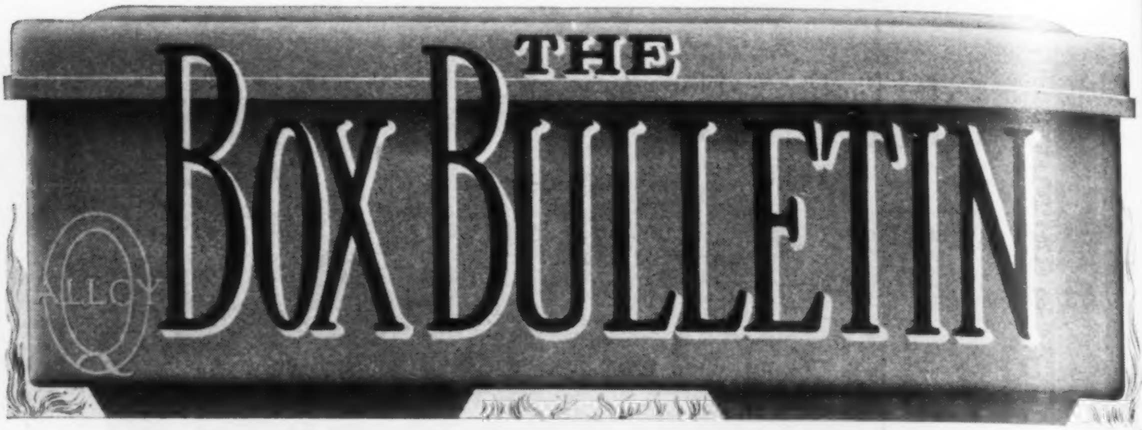
That ye may know from trouble ye
are free,
Safe in the knowledge that the qualitee
Built in *your* boxes is beyond compare
That safely through the coming year
ye'll fare.

If the act and wisdom of thy fellow man, serves as guidance to thy purse, and wise are they who serve in thy heat treat, 'tis Q-Alloys that they'll advise, and if thy boss is also wise and specifies the stuff he buys, 'tis certain that ye'll all agree, that now, and not eventually, is time for you to take your Q and standardize. The profits that in '23, ye've lost, can be returned to thee, in 1924, so tarry not, and don't delay, just send an order right away as Cadillac and Buick do and Ford and Dodge, and Reo too. Just come right out for Q-Alloy, and cease experimenting; they'll always be new things to buy, and oodles more "inventing"; buy now, and quit your shopping round, if Q-Alloys ye pick, ye'll know that thy investment's sound and they will turn the trick.

le envoi
Seek thee economee
But also qualitee
For true Economee
Is buying Qualitee.

—KRIT IKLEPOINT

BOX BULLETIN SUPPLEMENT



GERMAN MARKS

Fifty thousand German marks can be bought for five cents, but dollar bills are worth their face value. You can buy so-called cheap alloy boxes at one-third to one-half the price of Q-Alloys, but good sense tells you that "something for nothing," is not to be had in alloy boxes and pots, or in any other commodity.

Cheap carbonizing boxes are never worth more than the cheap price. Q-Alloy boxes are an investment that is worth the price and Q-Alloy prices are the lowest at which dependable alloys can be sold.

Our experience in furnishing our hundreds of customers with Q-Alloy and their decision to standardize on Q-Alloy is your protection.

This is the era of standardization—the decision to standardize on any material can be made two ways:

1, by trial of material in question.

2, by studying the performance of said material by other users.

In making your decision to standardize on Q-Alloy, we recommend your trying Q-Alloy to enable you to draw your own conclusions. A study of the service of Q-Alloy to other users will only strengthen your decision for trial. Let our well-trained organization work with you and solve any box or pot problems you may have.

The above picture
shows two partial shipments to

REO MOTOR CAR COMPANY

and

HUDSON MOTOR CAR COMPANY

Neither of these orders had been received more than 10 days prior to this shipment; 36,000 lbs. were shipped well within 30 days from receipt of these orders.

THIS IS TYPICAL OF GENERAL ALLOYS SERVICE


Heat Treating Furnaces
Tube Furnace
Oven Equipments
Bread-Baking Ovens
Solder Pots
Glue Pots
Electric HEAT
WESTINGHOUSE ELECTRIC
Electric heat has many users. A few of these applications are suggested by the small sketches. Electric heat can be used in your business.
Strips of Electric Heat
Right now is the time to install them; when Jack Frost is beginning to reach out with his cold fingers to nip some of those exposed pipes—when the watchman begins to visit the boiler room frequently because his shanty is so cold—when you begin to realize it is almost cruelty to ask a man to work all day in a cold crane cab.
Westinghouse electric space heaters save all this inconvenience. They are inexpensive, easy to install, and do not cost much to operate. Let your electrician wire up a couple of space heaters in some of those hard-to-heat places, and see how nicely they take the chill off on a cold morning. No fumes, no dirt, no flames to start a fire. Just turn on the heat when you need it, and turn it off when you are through.
A postal to the nearest Westinghouse office will bring sizes and prices. Better hurry, before cold weather sets in.
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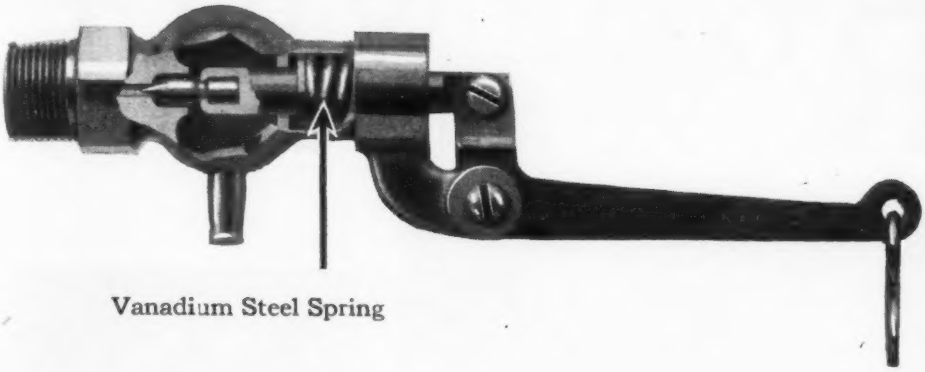

Vanadium Steel Spring

Testing A Vanadium Spring By More Than 1,000,000 Compressions

AN important feature of the Reliance Gauge Cock, made by Reliance Gauge Column Company, Cleveland, Ohio, is the Vanadium Steel Spring which holds the monel metal valve disc against the seat, under a water pressure of 750 pounds.

In a test, a Reliance Gauge Cock was operated mechanically more than 1,000,000 times—the spring being compressed and expanded with each operation. After the test the gauge cock was placed in service, without replacement of the spring or other part.

When the manufacturers first brought on the Reliance Gauge Cock they experienced considerable trouble with springs of carbon steel. Since the adoption of Vanadium Steel, they have not had a complaint on the springs.

Perhaps there is a possibility of improving your product or reducing your manufacturing costs through the adoption of Vanadium Steel in some vital part. May we look into the matter with you? A request for our assistance will not obligate or commit you in any way.

VANADIUM CORPORATION OF AMERICA

120 Broadway, New York Book Building, Detroit

VANADIUM STEELS

for Strength, Toughness and Durability

"RED CUT COBALT" HIGH SPEED STEEL

LIBERTY MACHINE SCREW CO.
HIGH GRADE SCREW MACHINE PRODUCTION
326 WARREN AVE. EAST
QUALITY FIRST – SERVICE ALWAYS

DETROIT, MICH.

July 24, 1922.

Vanadium-Alloys Steel Company,
Detroit, Mich.

Attention Mr. McFarland.

Dear Sirs:-

While you have not requested it, we feel that our recent success with "Red Cut Cobalt" on one job in particular merits a word of praise from us.

Under the following conditions, this steel being used for a cut off gave us 35 1/2 hours service without grinding.

Gridley, M. S. A. 1 3/4" Machine, 1 1/8" Stock, Bess Screw Steel. Machine Speed Approx. 450 R.P.M. and cutting speed 120 ft. per minute.

This is particularly gratifying in view of the fact that the life of the tool was approximately 35% greater than any other we have used.

Very truly yours,

LIBERTY MACHINE SCREW CO.

35% Greater Life Than Any Other Tool Steel Bit They Had Ever Used—

That, in a nutshell, tells the story of RED CUT COBALT in the plant of the Liberty Machine Screw Company.

The letter reproduced herewith is typical of many we are constantly receiving, telling of the remarkable success and efficiency of RED CUT COBALT for deep cutting service, fast speeds, or where hard or scaly materials prevail.

A trial order will convince you of the superiority of this high grade tool steel.

VANADIUM-ALLOYS STEEL COMPANY

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To the Members

Please advise us of your last change of address so you may have prompt receipt of the Society publications. Make it possible for us to give the service that you expect and we want to give.

Fill the form below and mail today

American Society for Steel Treating, ...1923
4600 Prospect Auenue,
Cleveland, Ohio.

Gentlemen:

Please check my address record and change it to agree with the following:

Name..

New Mail Address ....

Business Address..

Position or Title ....

Old Address was ....

CLASSIFICATION OF MEMBERSHIP

American Society for Steel Treating

The following paragraphs from the Constitution should enable you to properly fill the application form on opposite page.

Art. V. Section 4. "A MEMBER shall be a person engaged in work relating to the arts and sciences of iron or steel who is 21 years of age or over and who is not in the Sales Department of any firm dealing in or manufacturing metals, materials, supplies, equipment or any apparatus of whatsoever nature used in the art."
Dues $10.00 per annum.

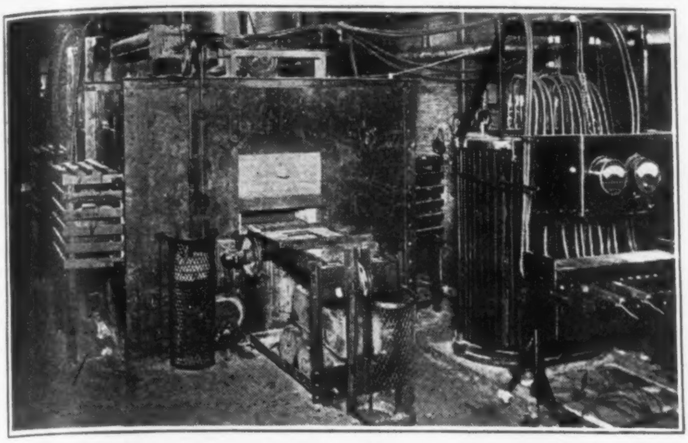
Art. V. Section 5. "An ASSOCIATE MEMBER shall be a person engaged in work relating to the arts and sciences of iron or steel who is 21 years of age or over, and who is in the Sales Department of a firm dealing in or manufacturing metals, materials, supplies, equipment, or apparatus of whatsoever nature used in the art."
Dues $15.00 per annum.

Art. V. Section 6. "SUSTAINING MEMBERS shall be those, who because of exceptional interest in the work of the Society, contribute financially for the promotion of its objects."

Membership in this class will be awarded to those who contribute to the Society not less than $25.00 yearly. $5.00 of this contribution is for one year's subscription to the Transactions of the American Society for Steel Treating. These contributions may come from either individuals or corporations and in either case will be acknowledged by the printing of the name of the donor in each issue of the Society's Transactions under the caption, "Sustaining Members."

Art. V. Section 7. "A JUNIOR MEMBER shall be a person interested or engaged in work relating to the arts and sciences of iron or steel who is in attendance as a student at some institution of learning, or if otherwise engaged, under 21 years of age."
Dues $2.50 per annum.

All dues are payable immediately upon notification of election to membership and are for one year from date of said election. Following payments are due upon same date each year. If a member desires his dues may be paid in two equal installments.



Electric Steel Treating Furnace insulated throughout with SIL-O-CEL

To Secure Uniform Heat and Positive Temperatures

apply to your furnaces a layer of SIL-O-CEL Insulation.

SIL-O-CEL is light in weight, highly siliceous, and possesses the lowest heat conductivity of any known material. It withstands extremely high temperatures, acting as a barrier to heat flow through walls and settings, and making it possible to regulate heat with absolute accuracy. Furnished in the form of brick, block, powder and cement, adapted to all types of equipment without change in design.

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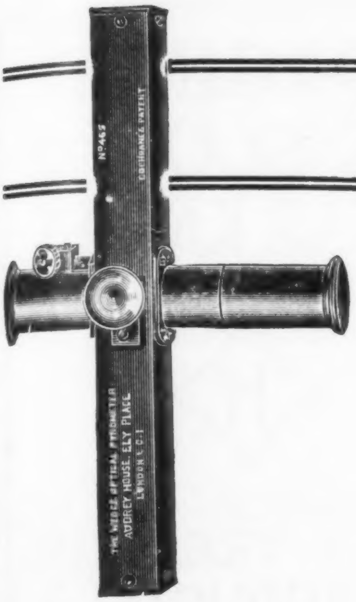


A Plant Instrument for Accurate High Temperature Control

Here is a simple yet highly accurate instrument for use in measuring higher temperatures in metallurgical operations where other pyrometrical methods are inadequate.

It is portable, and may be used by any intelligent worker, since no special training or knowledge is necessary. The

WEDGE
Optical Pyrometer

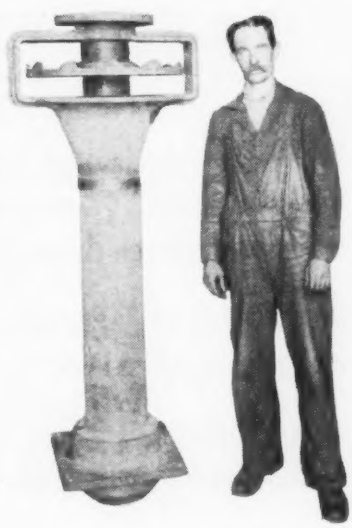
has a range from 525°C to 2100°C (or Fahrenheit equivalent) giving checking readings with 10° or less. Investigate its adaptability to your process.

Send for copy of our new booklet, "Notes on Optical Pyrometry".

American Kreuger & Toll Corporation

522 Fifth Avenue **New York City**

Four furnaces, each equipped with three Surface Combustion Velocity burners as illustrated, are giving rare service in a Southern steel plant.



From a small carbonizing furnace to a complete high pressure plant layout, you can depend upon Surface to deliver economy, satisfaction, service.

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Progress is the Product of Collective Achievement

"**FIRE ARMOR**" was built to perform a superior metallurgical and engineering service. That service is being performed daily in a steadily increasing number of the largest plants.

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PHONE ALBANY 5308

CHICAGO. U.S.A. Nov. 14, 1923

Chrobaltic Tool Co.,
Railway Exchange Bldg.
Chicago, Ill.

Attention: Mr. L.H. Whiteside.

Gentlemen:

We are using your "FIRE ARMOR" boxes for pack hardening at temperatures as high as 2400° F. on the outside of the box, and have never had a failure. Some of the boxes have seen as high as fifty heats of about three hours each, and still are apparently as good as new.

We are also using FIRE ARMOR pots for Lavite baths at a bath temperature of over 2000°F. and to date the results look very favorable. We have succeeded in obtaining a pot life of about 75 hours in contact with the molten Lavite and expect to double or triple this figure easily. We have found no evidence of chemical action between the pot and the solution.

Hoping that this is the information you desire, we remain

Yours very truly,

STEWART MANUFACTURING CORP.

D. L. Colwell
Metallurgist

DLC-MS

Quality—Dependability
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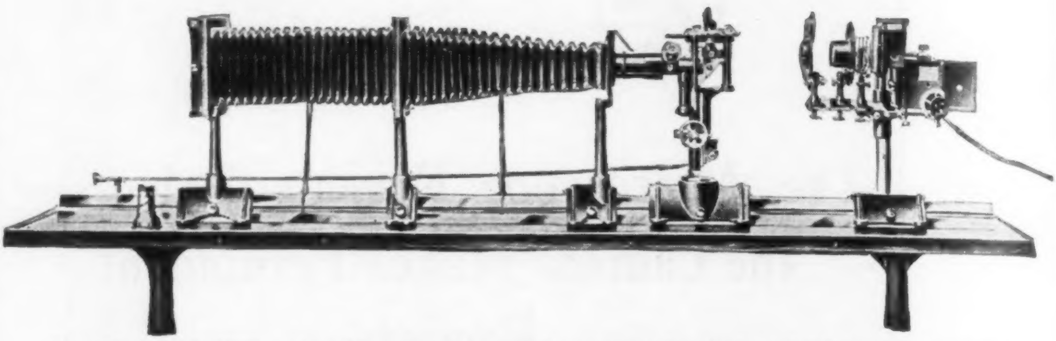
Leitz "Micro-Metallograph"

—Large Metal Microscope with Camera—



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Micro-Analysis are the only dependable methods towards improving manufacturing conditions in mills and foundries; without them tests are mere guesswork, production is unreliable and costly.

Inform us of your manufacturing problem, our technical department will assist you and make recommendations of the equipment needed for your laboratory.

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